Volume 48. September 1934. $4.00 a Year.
Number 3. Pages 255-382. $1.25 a Number.

JOURNAL

OF THE

New England Water Works Association.

ISSUED QUARTERLY.

PUBLISHED BY
THE NEW ENGLAND WATER WORKS ASSOCIATION,
613 Statler Building, Boston, Mass.

Entered as second-class matter September 23, 1903, at the Post Office
at Boston, Mass., under Act of Congress of March 3, 1879.

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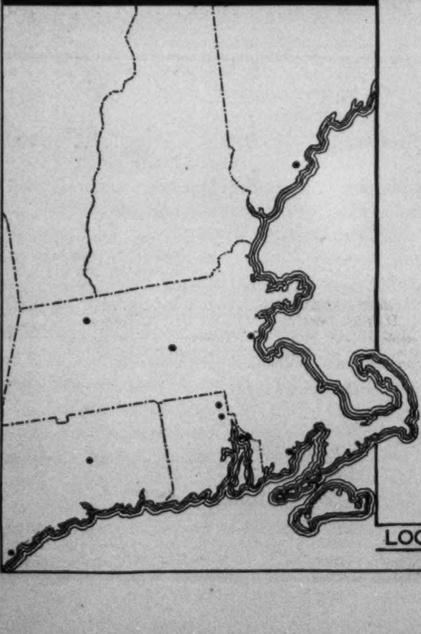

Hartford, Conn.
1918 48″
1927–8 30″
1929–30 42″, 36″

Portland, Me.
1923 54″
1924 54″
1931 48″, 42″

New Bedford, Mass.
1923 60″
1924 48″

Worcester, Mass.
1925 15″ to 54″

Pawtucket, R. I.
1926 54″, 60″, 48″
1930 54″

Providence, R. I.
1926–7 48″, 60″

East Providence, R. I.
1934 66″, 30″

Boston, Mass.
1927 30″

LOCK JOINT PIPE JOBS

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New England Water Works Association
ORGANIZED 1882.

Vol. XLVIII. September, 1934. No. 3.

This Association, as a body, is not responsible for the statements or opinions of any of its members.

SOME PHASES OF SOUTHERN NEW ENGLAND HYDROLOGY.

DISCUSSION OF PAPER BY CALEB MILLS SAVILLE.[*]

Charles W. Sherman.[†] There are two or three points in connection with the subject of rainfall records, which, in my opinion, are worth bringing to the attention of this Association at this time. These relate particularly to the correctness of rain-gage records and the representative character of the particular rain-gage records used in hydrological studies.

Mr. Saville mentioned early in his paper the record of the Cochituate rainfall, which was started within a year or two from the time the Cochituate supply was introduced into the city of Boston. Desmond FitzGerald, Past President of this Association, came to the Boston Water Works in 1872 as superintendent of the Cochituate division, his work having to do with the collection of the water supply. Not very long after that, he discovered a gage can with a funnel-shaped edge soldered to it. He became curious and found out that this device had been used for an uncertain number of years as the rain gage at Lake Cochituate. Presumably the original can was cylindrical and was a reasonably good type of rain gage, but presumably also the attendant who was reading the rain gage was not quite satisfied with the records he was getting; consequently he soldered a piece of tin to the top of the rain gage to increase the diameter. According to Mr. FitzGerald's belief, as expressed to me, that can was used to measure the rainfall, and the resulting published records of rainfall must have been absolutely worthless, or worse than worthless, because they are misleading. If that is so, the published records of rainfall at Lake Cochituate, down to 1868 or 1870, should not be given any credence whatever.

Another point has to do with the representative character of the rain gages on which we place dependence. For a great many years, the average rainfall over the Sudbury River drainage area has been computed by taking the arithmetic mean of the records of four rain gages at different points in the watershed. The gages naturally have been located at places where they were convenient for an observer to take records. I am not criticizing the

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[*] This Journal, Vol. 47, No. 4, Dec. 1933, pp. 363–448.

[†] Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

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*This Journal, Vol. 47, No. 4, Dec. 1933, pp. 363–448.

†Of Metcalf and Eddy, Consulting Engineers, Boston, Mass.

Another point has to do with the care which is given to keeping the rain gages in proper condition, by that I mean, leveled up, emptied after the rain has fallen, the effect of frost in heaving the rain gage foundation eliminated, or various other things which must occur to any one of you who has had anything to do with rain-gage records. I have in mind particularly a water-works system — not in New England — which I had occasion to study in some detail a few years ago, where they maintained probably a dozen rain gages. One of them was located about 150 ft. from the caretaker's house, where it was easily accessible for reading, and, like a great many other rain gages in use over the country, this one, instead of being set on the ground, was mounted on a post. The rain gage was of a type in which the collecting cone and interior vessel are taken out during the winter and only the outer can is used for collection of snow. At the time I examined it,— as I remember, it was either in July or August,— the cone and central part had not been replaced; it was still in the condition that it was intended to be in for winter use. That may not have had much effect on the accuracy of the records taken but it may have had some effect. However, what certainly did have an effect was the fact that the frost had heaved the stake considerably out of plumb, so that for a guess the edge of the rain gage was 10 degrees out of level.

The exposure also has an effect on the catch of a rain gage. Some years ago we had occasion, in studying the records of New England precipitation for the design of storm-water drains, to go into the precipitation records at Springfield, Mass. The station maintained at the United States Arsenal has been kept up for a great many years. That is the record which is published by the Weather Bureau as the Springfield rainfall. In addition to that there is a recording gage which I believe was started by the water works, originally on the roof of its old Bridge Street office, back in the decade of 1870, and continued until somewhere about 1908 or 1910, when there was an interim of something like a year, I believe, while the new municipal buildings were being put up; later the gage was reëstablished on the roof of the new City Hall, somewhat higher above the ground, but probably at a place where the ground surface was not very different in elevation. During the time of storage, or in being taken down or being reset, it is probable that the edge of the gage was damaged, and most likely a coppersmith was employed to set it up and to provide the connecting pipe leading to the recording mechanism in the building below; when he made the repairs he put on a new rim with a rolled edge instead of a sharp edge, and a half inch greater in diameter than the original one. As a result, something like ten years of record were accumulated on the chart for a collector half an inch greater in diameter than it was supposed to be, the resulting records were of course in error. That is one of the things that may happen if the man who is supposed to be on the job does not give personal attention to such matters, or have someone who is interested and knows what these things mean follow them up.

The question of how much elevation above the surface of the ground had a bearing on the correctness of the gage was of interest. Although the Arsenal gage was at a distance of two or three miles from the City gage and was on the plateau rather than on the river plain, perhaps 150 ft. higher in elevation above the city, the only way we had of trying to connect the records of the two gages was to look at the total catch in specific storms or in different months, as shown by the ordinary type rain gage maintained as an official gage and the city's gage. We found, that in the earlier years there was comparatively little difference in the readings, although this elevated gage, as would be expected, gave slightly less catch than the ground gage at the Arsenal. As time went on, the differences decreased, passed zero and increased in the other direction; and when we made the studies about 1925 the elevated gage was giving a catch of 10 to 12 percent. greater than the surface gage after correcting for the error in the collecting can. We then made an inspection of the conditions at the Arsenal and discovered that two or three trees, which very likely were not in existence at the time the gage was started — if they were, they must have been mere saplings — had grown to such a size that they were almost overhanging the gage. On one tree especially, the outer branches were practically over the gage, and one or two others were so near that their effect on wind currents must have been very severe. This brings forcefully to mind the idea that periodic inspection of all rain gages by some person who knows what conditions may affect them is an extremely important matter.

Where gages are operated as or maintained as coöperating stations with the Weather Bureau, I firmly believe that it would be greatly to the advantage of everybody who has anything to do with studying rain-gage records if the National Government could make available sufficient money to provide a competent man in each district to make an inspection at least once in five years of every gage from which the records are turned into the Weather Bureau, and see whether the exposure is still reasonable, what kind of care the gage is getting, and how the records are kept.

MR. SAVILLE. What Mr. Sherman has said of course is absolutely the fact in all of the matters that he has mentioned. We have to remember, however, that we must use what data we have, but use them with judgment.

There are two different uses for rainfall records. One of them is for water-supply purposes, and there it is usually tendencies towards drought rather than the individual records which are important, except in case of spillway design. In the case of sewage works or drainage works, it is usually maximum individual storms that are of the most importance.

In the matter of our West Hartford gage, it was located originally in a very good place and had not been changed during the period of sixty-five years. Bearing in mind that there might be some question that might arise on account of exposure for the last two or three years, we have had another gage within perhaps 100 ft. of the regular one as a check, to show what the conditions were, because we realized that trees might have grown, as they have, and that there might be some other matters that would be of detriment to the record.

Mr. Sherman spoke of the inadequacy of one rain-gage, or at least two, perhaps, to determine the rainfall on a very large area. It has always been rather a source of amusement to me in looking up records, to find this condition, which at best is only an assumption of the total rainfall on the area, and to obtain the runoff by a weir on a stream, taking very careful measurements to the very last notch; that is, you are very, very careful to get scientific accuracy on the discharge from that weir, and take it for granted that the rain gage is as representative of total rainfall.

To obviate any difficulty in that connection, on the West Hartford watershed, we have four other gages located at various points on the watershed, and they all check fairly well. On our Nepaug and West Branch areas each, we have seven rain gages scattered over the district. These gages are inspected by some members of our engineering staff and are given attention to keep them in order and see that the observers are carrying on properly. The entering streams all have standard weirs. Besides the standard rain gages, there is one automatic rain gage on each of these stations also, so that we feel, as far as our rain fall is concerned on those areas, that we are pretty well covered. Mr. Sherman's statement, however, about location and changes that occur in rain-gage conditions is perfectly correct.

We have what is known as our Canton record. That record started in 1850. It is not very far from our Nepaug water supply, and for some time came along with that record. During the period of the Canton record, there occurred the largest rainfall that has been experienced in this part of the country, I think, in the middle of the last century. Undoubtedly that gage — we have discontinued it now — was of very limited value during recent years at least, so far as accuracy of individual determinations are concerned. When it was first established, it was in an open field, and it could very readily be representative of the rainfall. Within recent years, and at the time it was discontinued, the part of the town in which it was located had developed considerably, houses had been built and trees had grown, so that the conditions were very different from what they were when the record was first begun. For that reason, we decided to discontinue this station, although we carried it forward for about ten years in parallel with one of our other rain gages, so that the records might be continuous.

I think, for water-supply purposes, it is the general tendency which counts. We are interested to know particularly whether there are going to be periods of more excessive drought than we have expeienced in the past. These we must determine on the basis of the records that we have. If we find that we have recently experienced about as little rainfall as there has been probably in the last one hundred years, it would seem that we could safely figure on that basis. We are more interested in trends in water-supply work than we are in individual rain storms, but the individual rain storms are necessary for drainage work.

In the English records there is a classical example very similar to what Mr. Sherman has spoken of on the growth of trees. When a rain gage which had been depended on for a great many years was examined, it was found that there was a yew tree which had grown over it and partly shaded it, so that condition had to be taken into consideration, but even that record was of much more value than none at all.

John R. Weeks.*† From thirty-eight years of experience in the field in charge of rainfall observers, rainfall reports, and river and flood districts in a territory extending across the South from Arkansas and the headwaters of the Arkansas River to Georgia and the Altamaha River, and across the North from Montana and its varied water storage conditions to New York and the upper Susquehanna River, I can heartily agree with the conclusions set forth by Mr. Saville on page 363 of his paper.

Regarding the remainder of his paper I comment briefly as follows. On page 365 the statement is made that "floods are the antithesis of droughts." This needs considerable qualification since floods of strong characteristics are brought about by synchronism of flood crests in tributary streams, progression and sequences of rainfall over the watershed, local convectional overturning with resultant cloudbursts, etc. Indeed, on small streams and in small watersheds record floods may occur in a drought period. An example is the record flood in the Patapsco River in Maryland, July, 1868. Furthermore, a very wet month may occur in a drought period, as the month of September, 1882, at West Hartford, Conn.

The chart on p. 373 seems to have been taken from a large map of precipitation for the United States, drawn to a rather coarse scale and based on a limited period of years. The map, is incorrect for Maryland and Delaware. Much better maps for limited areas can now be drawn from the rainfall averages of *all* rainfall stations, including "coöperative stations," with fifteen years or more of record, all the records being reduced to a homogeneous period of thirty-five years, 1898 to 1932. The computations have just been completed for the Weather Bureau by Civil Works employees operating under direction of the Weather Bureau section directors for each state, and the data can be obtained on application to the various Weather Bureau section directors. The section center for New England is at Boston.

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*Section Director, U. S. Weather Bureau, Baltimore, Md. †By letter.

The work has been done primarily for a revision of the Atlas of American Agriculture, the 20-year averages previously used having proved inaccurate. But the results will be very valuable to engineers as well.

The rule by Rafter, cited on p. 374, was derived from a rather short period of record that happened to be somewhat moderate in its rainfall extremes. It holds good for Baltimore for the period 1878 to 1927 (maximum 62.35 in.; minimum 31.57 in.) but fails completely for the preceding fifty years and for the fifty years 1883–1932 (maximum 62.35 in.; minimum 21.55 in.). The rule would be better if it read one-third the maximum rainfall instead of one-half.

It should be kept in mind that probability curves (p. 381) fall down if the statistical "sample" is not a good one. In meterology such curves may be misleading.

The discussion of the cause of precipitation (p. 407) ignores summer conditions, when the land is warmer than the water, convectional overturning dominates, and the land slope effect is reduced or, in drought seasons, may be nullified. The frequency of thunderstorm development is an important factor in determining whether a drought period is severe in its effects or not.

In his discussion of normals (p. 409 et. seq.) Mr. Saville's expression "government stations" evidently means "first order" Weather Bureau stations, most of which are located in large cities. These form too coarse a network for most water-supply investigations and are greatly out-numbered by the climatological, river and flood, cotton region, and other coöperative rainfall stations. The averages of all these are being reduced to the 35-year period 1898 to 1932 at the present time, thus forming a finer network of stations and affording more correct "normals" than have heretofore been available. The data will be very valuable in further discussion of water-supply problems. Furthermore, in the revision of Weather Bureau Bulletin W, Climatological Data of the United States by Sections, interpolation has been made of missing parts in the station records so that the averages, etc., are made more complete.

The note on p. 411 states "Averages from 1868–1875 not plotted because of abnormal departure." The period was a drought period and should have been used. The curves of the chart would then more nearly correspond with actuality, though it is true that the observations were not so well taken in the years immediately following the war as from 1880 on.

The chart on p. 420 should not be taken at its face value, and there is a serious error in the Monthly Weather Review paper from which the upper curve is taken. Running sums of departures magnify any systematic errors of observation and are excellent for determining, roughly, such errors. Running totals can also be used and the method is old. When departures are used the base selected is important in fixing the trend of the curve. If the base is too high the trend may be downward, while if it is too low, using the same data, it may be upward. In the chart under consideration the base used for Boston from 1750 to 1849 is too high and from 1850 to 1930 it is too low, giving very deceptive trends to the curve for both periods. Furthermore, the inflection at "B" (1849) is undoubtedly due, in part at least, to the improvement in methods and care in measuring rainfall brought about by the efforts of Loomis, Espy, the New York State Regents, the Smithsonian Institution, the Patent Office, and the Agricultural Department. Professor Loomis said to the meeting of the American Association at Albany, N. Y., in 1851,* "We encounter a difficulty arising from the want of a continuous register of the fall of rain at a single locality for any long period. In this country, accurate observations extend only over a period of 25 years. And these are only known at one point, which is at Albany. These were taken under the direction of the Regents of the University." The record for Boston used by Blodgett† begins in 1842 and was made at the Cambridge Observatory. For temperatures at Boston, however, he uses a combination of observations at Cambridge, Salem, Boston, Watertown, and Cambridge Observatory extending back to 1780.

It is questionable whether the combination of monthly rainfall counts at a number of stations to form a histogram for the district (p. 428) gives a true picture or a true district mode. Should not the *average* rainfall for the district for each month be used in making the histogram? Moreover, statisticians are too fond in making meteorological histograms of smoothing the derived curve and computing the mode, etc., by mathematical formulae which have been developed in other fields of work. Few meterological histograms really conform to chance and many of them have more than one mode, the reason for the different modes being apparent if daily observations and weather maps for the period are available. An‡ interesting example of such double modes in rainfall appears in the 100-year record for Philadelphia for the months of February, March, and April, 1820 to 1919, modes appearing at 2.81 to 3.20 in. and 4.41 to 4.80 in. (March), 2.41 to 2.80 in. and 4.41 to 4.80 in. (February), and 2.41 to 2.80 and 4.41 to 4.80 in. (April).

The mode (p. 441) is also more stable than the average and a normal mode can be more satisfactorily determined from a short length of record than can a normal mean. An excessive rain may count 10 in an average but it only counts 1 with respect to the mode.

Finally, conceding without question that the energy required at the earth to produce weather changes comes from the sun, if we believe, as many do, that the actual results in any one year in a given locality, so far as the unusual is concerned, are determined by chance combinations of *possible* conditions, then we can arrive at an estimate of the *possible* extreme minimum rainfall for the year by adding together the recorded values for the months of least rainfall. In this manner, for West Hartford, we obtain an annual rain of 5.63 in., which is about one-fifth of the rainfall recorded in several lean years of record. It can be assumed that the arrival of such an extremely dry year is *possible* but is *very improbable.*

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*Annual of Scientific Discovery, 1852, p. 390. †Climatology, p. 59.

‡See Monthly Weather Review, February, 1921.

MR. SAVILLE. Mr. Weeks' criticism of the statement that "floods are the antithesis of droughts" is well made in the broad sense in which the words "flood" and "drought" are generally used. In the present paper the study referred to the special purpose of water supply. In that restricted sense a "drought" is a period of such deficient rainfall that water-supply reservoirs or yields of watersheds are so severely affected as to produce general comment and perhaps alarm as to the adequacy of the supply for public use. On the other hand, a "flood," so far as water storage or use is considered, may be such a run-off as will cause excessive waste. The author agrees perfectly with Mr. Weeks that such floods as occurred in New England in November, 1927, cannot be considered as the antithesis of the periods of low yield experienced in this same locality in the early eighteen eighties, and in 1909–10 and 1930–31.

While a very wet month, such as September, 1882, at West Hartford, Conn., undoubtedly would bring about flood conditions, as generally recognized by valley dwellers, yet such a copious supply of water would be very welcome in water-supply business. Therefore, considered from a water-supply standpoint it might well be considered the antithesis of the drought of the previous months of the same year.

The map referred to on p. 373 was one supplied by the Weather Bureau to be used as an indication of general conditions.

Regarding the one-half rule quoted on p. 374 as used by Rafter, the earliest reference to this rule which has come to the attention of the author was that by G. J. Simons, in his discussion of the classical paper on rainfall by Sir Alexander Binnie.* While it is understood that this so-called rule is not intended for scientific accuracy, nevertheless its results are astonishingly close to the mark. On p. 369 a quotation from work of Prof. Oliver L. Fassig of the Weather Bureau (retired) gives rainfall "dependability" i.e., $\frac{\text{annual maximum}}{\text{annual minimum}}$ as 1.77 for Massachusetts, 1.92 for Rhode Island and 1.84 for Connecticut. An average of 71 stations in Southern New England with records of from 35 to 118 years and an average length of 60 years give an average ratio of annual maximum to annual minimum of 1.975 $(\frac{61.22}{31.04})$.

Mr. Weeks was apparently mislead by the note on p. 411: all of the records from 1868 (the beginning of the record) were used, but on account of the wide variation the early ones were not plotted, as the purpose of the diagram was to indicate the wide spread in averages even in long-period records.

In regard to the chart on p. 420, taken from the Monthly Weather Review, the purpose of its inclusion was to call to attention the cyclic variation in rainfall; for this purpose it seems admirable regardless of whether or not criticism may be justified in its makeup.

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*Proc. Inst. C. E., Vol. 109, p. 58.

John C. Hoyt.[*][†] Until recently, detailed discussions relative to rainfall and run-off, such as are presented in Mr. Saville's paper, have been impossible owing to lack of adequate reliable data. In general, records of precipitation and stream flow in the United States have been made available through the United States Weather Bureau and the United States Geological Survey. Unfortunately, neither of these sets of records extend over periods long enough to afford an adequate basis for most hydrologic studies. Precipitation data are incomplete and scattered prior to 1889, figures of monthly precipitation by states were not made generally available until about 1890, and the mean annual precipitation by states has not been computed for years prior to 1881. Systematic records of stream flow on a country-wide basis were started in 1895, and there are but few continuous records that began prior to that date. Therefore, it has only recently been possible to make any studies based on definite information covering a period approaching 50 years.

In water-supply studies it is important to remember that the factors that determine the quantity and distribution of water in streams include climate, vegetation, topography, geology, geographic location, and the works of man. It is difficult to differentiate the effects of these factors. The effects of topography, geology, and geographic location are practically permanent. The effects of the other three factors, however, vary from time to time. The laws governing them have not been fully developed, and in general their magnitudes are not demonstrable. Only their tendencies can be considered. They affect stream flow, however, in one or both of two ways — first, in the total yield, and second, in the seasonal distribution of the run-off. Any factor may affect the flow directly or may operate indirectly by its influence on one of the other factors. It is noteworthy that whereas the features of climate, especially precipitation and evaporation, including transpiration through vegetation, enter largely into the distribution of run-off, they also practically determine its total amount. The other factors, except as they affect climate, exert their influence principally on the distribution of flow and only slightly on the total quantity of discharge.

Mr. Saville has made a valuable contribution, and it is hoped that as adequate information becomes available, similar papers will appear covering other areas. Whether or not such papers serve as a basis for deducing principles or laws, they will give a fuller knowledge, which will act as a guide in hydrologic studies. Conclusions, of course, will vary, depending both on differences in conditions that exist in different basins and on differences in the points of view of different investigators.

There are three statements in Mr. Saville's paper relative to which there may be a difference of opinion. They are the conclusions numbered 5 and 6 on page 363 and the fifth paragraph under "Rainfall studies" on page 364.

That even a 35-year rainfall record may "be dependable within 2½ per cent. of normal (plus and minus)" or "that run-off records for a period of 20 years can be expected to give dependable results hardly closer than 10 to 15 per cent." may be difficult to substantiate.

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[*] Hydraulic Engineer, U. S. Geological Survey, Washington, D. C.

[†] By letter.

Before reliable run-off records were available, many engineers having to do with run-off studies held that rainfall records gave a much better criterion of the capacity of a drainage basin than run-off records. This idea has in the main been discarded. The possible degree of accuracy in determining the rainfall over a given drainage area is problematical — probably not within less than 5 to 10 per cent. The run-off from an area can be measured within less than 5 per cent. On the assumption that the rainfall and run-off records are of equal accuracy, computed run-off based upon rainfall is subject to greater errors than measured run-off, on account of the various factors which determine the amount of rainfall that appears as run-off. In an area where meager flow data are available, it has been observed that records of run-off from an adjacent similar area serve as material aid, in connection with rainfall data, in determining the run-off. This is especially true if there is a short period of simultaneous run-off records from the two areas. Any estimate of run-off from a drainage basin that is not based upon actual measurements is necessarily liable to considerable error.

In studying the drought of 1930–31, the minimum discharge in second-feet for selected rivers in the United States has been tabulated. This tabulation indicates that for some of the streams the minimum monthly discharge for most of the months occurred during consecutive months in 1930 and 1931. On the assumption that the minimum for each of the 12 months as determined by available records established the future minimum that may be expected, their mean can be taken for what may be called the theoretical low-water year. To lower this minimum would require 12 consecutive months during which there were no flows greater than those previously recorded, unless there were a few months in which the flow was enough smaller than the previously recorded minima to more than offset the months in which it was greater. The probability of another year with a sequence of so many low-water months is remote. Therefore, 1930 and 1931 will probably serve for some time as a basis for estimating low-water flows on many streams throughout the United States.

The minimum discharge for selected rivers east of the Mississippi River is given in the following table:

MINIMUM DISCHARGE, IN SECOND-FEET, OF SELECTED RIVERS IN THE UNITED STATES.

	NORTH ATLANTIC SLOPE BASIN.							
	Pisquataquis River near Foxcroft, Me.		Merrimack River at Lawrence, Mass.		Susquehanna River at Harrisburg, Pa.		Potomac River at Point of Rocks, Md.	
Drainage area — sq. miles	286		4 672		24 100		9 650	
Period of record	1904–31		1880–1931		1891–1931		1897–1931	
Mean Year	666		6 610		35 000		9 400	
Minimum Year	436 in 1924		4 130 in 1930		21 600 in 1931		3 800 in 1930	
Maximum Year	1 080 in 1907		10 600 in 1888		52 600 in 1891		14 500 in 1902	
Month.	Minimum.	Year.	Minimum.	Year.	Minimum.	Year.	Minimum.	Year.
January	61.6	1918	1 589	1925	3 880	1931	2 370	1931
February	52.3	1920	2 127	1931	9 120	1931	2 930	1931
March	141	1926	3 374	1885	32 200	1931	5 400	1931
April	940	1926	7 961	1915	27 800	1925	4 370	1915
May	442	1921	4 359	1903	13 100	1896	3 280	1930
June	68.8	1921	2 179	1915	11 200	1925	2 230	1930
July	47.9	1921	1 184	1911	6 500	1911	1 100	1930
August	36.8	1924	1 362	1913	2 880	1930	771	1930
September	23.9	1923	1 217	1883	3 400	1930	834	1930
October	41.5	1910	1 335	1910	2 360	1930	706	1930
November	39.0	1910	1 575	1908	2 300	1930	914	1930
December	60.6	1929	1 490	1910	3 830	1930	1 450	1930
Average	163		2 480		9 880		2 200	
Minimum Period.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.
1 month	23.9	Sept., 1923	1 184	July, 1911	2 300	Nov., 1930	706	Oct., 1930
2 months	38.0	Aug., 1914	1 322	July, 1911	2 330	Oct., 1930	770	Sept., 1930
3 months	40.3	Aug., 1914	1 527	July, 1911	2 690	Sept., 1930	770	Aug., 1930
6 months	71.0	July, 1914	1 739	July, 1910	3 110	Aug., 1930	963	July, 1930
9 months	159	June, 1924	2 240	June, 1910	6 460	June, 1930	1 480	June, 1930
12 months	364	June, 1924	3 480	Sept., 1910	13 500	Apr., 1930	2 460	Apr., 1930

MINIMUM DISCHARGE, IN SECOND-FEET, OF SELECTED RIVERS IN THE UNITED STATES — Continued.

	SOUTH ATLANTIC SLOPE BASIN.						EASTERN GULF OF MEXICO BASINS.			
	James River at Cartersville, Va.		Yadkin River near Salisbury, N. C.		Santee River at Ferguson, S. C.		Chattahoochee River at West Point, Ga.		Coosa River at Childersburg, Ala.	
Drainage area — sq. miles	6 240		3 400		14 800		3 550		8 390	
Period of record	1899–1931		1896–1931		1908–31		1897–1910; 1912–31		1917–31	
Mean Year	7 240		4 780		19 200		5 940		14 500	
Minimum Year	3 250 in 1930		2 750 in 1930		11 300 in 1927		3 020 in 1904		8 500 in 1931	
Maximum Year	11 500 in 1901		8 640 in 1901		30 500 in 1929		9 280 in 1920		24 000 in 1920	
Month.	Minimum.	Year.	Minimum.	Year.	Minimum.	Year.	Minimum.	Year.	Minimum.	Year.
January	2 500	1931	2 230	1904	10 800	1927	3 050	1914	11 400	1929
February	2 360	1931	1 940	1931	11 600	1911	2 320	1898	10 100	1931
March	5 130	1931	3 120	1931	10 100	1911	2 780	1898	7 080	1918
April	3 780	1925	2 370	1904	10 400	1927	2 930	1905	8 030	1925
May	2 710	1930	1 910	1926	6 470	1927	2 150	1914	4 910	1925
June	1 990	1925	1 500	1926	5 900	1911	1 490	1898	3 070	1925
July	967	1930	1 270	1930	6 280	1911	1 700	1925	3 230	1925
August	652	1930	1 300	1925	4 920	1925	578	1925	1 990	1925
September	561	1930	1 260	1925	3 430	1925	333	1925	1 400	1925
October	543	1930	1 120	1931	4 560	1925	360	1931	1 610	1931
November	912	1930	1 180	1931	4 320	1931	1 110	1931	2 230	1931
December	1 340	1930	1 790	1925	6 880	1917	2 290	1904	4 220	1917
Average	1 950		1 750		7 120		1 760		4 940	
Minimum Period.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.
1 month	543	Oct., 1930	1 120	Oct., 1931	3 430	Sept., 1925	333	Sept., 1925	1 400	Sept., 1925
2 months	552	Sept., 1930	1 150	Oct., 1931	4 000	Sept., 1925	456	Aug., 1925	1 700	Aug., 1925
3 months	585	Aug., 1930	1 280	Sept., 1931	4 300	Aug., 1925	700	Sept., 1931	2 140	Sept., 1931
6 months	829	July, 1930	1 600	June, 1930	5 710	June, 1925	1 270	June, 1931	2 880	June, 1931
9 months	1 320	June, 1930	1 960	June, 1930	7 310	Apr., 1925	2 290	Apr., 1925	5 240	Apr., 1925
12 months	2 100	Apr., 1930	2 270	Apr., 1930	9 420	June, 1926	2 810	Dec., 1930	7 180	Dec., 1930

Minimum Discharge, in Second-Feet, of Selected Rivers in the United States — Continued.

	Ohio River Basin.													
	Allegheny River at Kittanning, Pa.		Hocking River at Athens, Ohio		Kanawha River at Kanawha Falls, W. Va.		Miami River at Hamilton, Ohio.		Kentucky River at Lock 10, Winchester, Ky.		Cumberland River at Nashville, Tenn.		Tennessee River at Chattanooga, Tenn.	
Drainagearea—sq. mi.	9 010		944		8 300		3 640		3 990		12 860		21 400	
Period of record	1906–31		1916–31		1872–1931		1910–31		1910–31		1888–1931		1881–1931	
Mean Year	16 100		1 010		13 000		3 760		5 210		20 800		38 300	
Minimum Year	10 900 in 1922		571 in 1925		5 430 in 1930		1 560 in 1931		2 120 in 1930		11 800 in 1904		22 000 in 1904	
Maximum Year	21 800 in 1927		1 480 in 1927		20 500 in 1901		5 880 in 1913		6 840 in 1927		31 300 in 1890		54 100 in 1882	
Month.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.
January	3 130	1918	75.5	1931	5 600	1931	580	1931	543	1931	4 530	1914	21 300	1904
February	5 310	1920	193	1931	5 870	1895	778	1931	2 030	1931	9 780	1904	23 700	1898
March	10 500	1915	262	1931	10 200	1925	1 510	1931	3 270	1910	14 800	1910	24 500	1931
April	10 500	1915	385	1925	8 150	1915	1 210	1915	1 720	1915	9 430	1915	22 100	1925
May	6 630	1926	179	1930	4 800	1930	1 120	1930	1 980	1916	5 480	1896	17 800	1896
June	2 860	1925	77.8	1930	2 550	1930	811	1914	234	1930	2 960	1931	10 800	1925
July	1 600	1923	23.1	1919	1 290	1930	492	1930	48.8	1930	1 410	1930	9 370	1925
August	637	1930	39.6	1930	1 390	1925	376	1910	34.2	1930	1 170	1930	4 760	1925
September	737	1930	44.8	1930	1 310	1930	527	1917	15.8	1930	796	1925	3 990	1925
October	746	1930	36.1	1930	1 130	1930	441	1928	15.0	1930	766	1894	5 510	1904
November	1 140	1930	50.5	1930	1 510	1922	457	1930	44.0	1930	950	1931	7 040	1931
December	4 360	1908	64.5	1930	2 690	1930	509	1930	107	1930	2 970	1913	12 500	1903
Average	4 010		119		3 870		734		837		4 590		13 600	
Minimum Period.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.
1 month	637	Aug., 1930	23.1	July, 1919	1 130	Oct., 1930	376	Aug., 1910	15.0	Oct., 1930	766	Oct., 1894	3 990	Sept., 1925
2 months	687	Aug., 1930	40.4	Sept., 1930	1 220	Sept., 1930	475	July, 1930	15.4	Sept., 1930	903	Oct., 1894	4 380	Aug., 1925
3 months	707	Aug., 1930	40.2	Sept., 1930	1 320	Aug., 1930	488	Oct., 1930	21.7	Aug., 1930	1 095	Sept., 1894	6 040	July, 1925
6 months	1 700	June, 1930	48.0	July, 1930	1 590	June, 1930	501	July, 1930	44.1	July, 1930	1 740	June, 1930	10 800	June, 1930
9 months	3 760	June, 1930	68.9	May, 1930	2 510	May, 1930	579	June, 1930	341	June, 1930	4 000	May, 1930	14 700	June, 1930
12 months	7 470	Apr., 1930	165	Apr., 1930	4 300	Apr., 1930	853	Apr., 1930	1 060	Apr., 1930	7 180	Apr., 1930	18 300	Apr., 1930

Minimum Discharge, in Second-Feet, of Selected Rivers in the United States—Concluded.

	St. Lawrence River Basin.				Hudson Bay and Upper Mississippi River Basins.									
	Wolf River at New London, Wis.		W. Br. Oswegatchie River near Harrisville, N. Y.		Red River at Grand Forks, N. Dak.		Mississippi River at Le Claire, Iowa.		Chippewa River at Chippewa Falls, Wis.		Rock River at Lyndon, Ill.		Kaskaskia River at Vandalia, Ill.	
Drainage area—sq. mi.	2 240		256		25 500		88 600		5 600		9 010		1 980	
Period of record	1914–31		1917–31		1898–1931		1874–1931		1914–31		1915–31		1915–31	
Mean Year	1 890		539		2 130		49 400		4 900		6 090		1 500	
Minimum Year	986 in 1931		419 in 1931		335 in 1931		24 400 in 1931		2 760 in 1925		2 920 in 1931		302 in 1931	
Maximum Year	2 490 in 1928		631 in 1918		5 860 in 1916		85 800 in 1881		6 840 in 1916		8 480 in 1929		3 690 in 1927	
Month.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.	Min.	Year.
January	601	1926	105	1918	130	1925	11 400	1890	831	1917	2 120	1931	25.3	1931
February	622	1926	130	1920	110	1912	14 000	1893	1 090	1917	2 620	1917	37.4	1931
March	969	1931	384	1924	282	1913	19 900	1931	1 370	1917	2 260	1931	97.9	1931
April	1 160	1931	495	1927	1 090	1931	26 000	1931	3 250	1931	2 850	1931	240	1931
May	901	1931	256	1921	612	1931	23 800	1931	1 980	1931	2 240	1931	253	1925
June	1 320	1931	120	1920	492	1931	21 500	1931	3 660	1926	2 290	1931	206	1931
July	853	1931	87.5	1923	277	1931	19 800	1910	2 040	1918	1 340	1931	104	1931
August	552	1931	52.8	1923	136	1931	15 800	1931	1 170	1925	1 130	1931	25.1	1930
September	575	1930	54.4	1921	59.5	1931	18 100	1930	1 340	1929	1 210	1925	25.4	1922
October	880	1930	105	1922	111	1931	20 100	1910	1 600	1929	1 400	1918	26.8	1930
November	893	1930	165	1930	200	1931	18 700	1891	1 850	1920	1 930	1918	21.1	1930
December	796	1925	145	1922	135	1931	13 100	1910	1 650	1917	2 040	1930	35.1	1930
Average	847		175		303		18 500		1 820		1 940		91.6	
Minimum Period.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.	Mean.	Beginning.
1 month	552	Aug., 1931	52.8	Aug., 1923	59.5	Sept., 1931	11 400	Jan., 1890	831	Jan., 1917	1 130	Aug., 1931	21.1	Nov., 1930
2 months	590	Aug., 1930	68.2	Aug., 1921	85.2	Sept., 1931	12 400	Dec., 1889	960	Jan., 1917	1 230	July, 1931	24.0	Oct., 1930
3 months	686	Aug., 1930	85.1	July, 1923	102	Aug., 1931	14 400	Dec., 1889	1 100	Jan., 1917	1 380	July, 1931	27.2	Nov., 1930
6 months	738	Aug., 1930	145	Aug., 1930	153	July, 1931	17 400	Aug., 1910	1 870	Sept., 1925	1 820	July, 1918	28.4	Aug., 1930
9 months	787	July, 1930	185	June, 1930	277	July, 1930	19 900	Aug., 1930	1 930	July, 1925	2 060	Jan., 1931	50.8	July, 1930
12 months	857	Sept., 1930	344	Sept., 1930	335	Jan., 1931	20 900	Sept., 1930	2 480	Apr., 1925	2 110	Oct., 1930	95.1	Aug., 1930

Mr. Saville. It is with the utmost appreciation of the work performed by the Surface Water Division of the U. S. Geological Survey in its gathering of hydrological data, and particularly the yeoman's service necessitated therewith by Mr. Hoyt and his associates, that I approach the discussion which Mr. Hoyt has so kindly and ably contributed. Differences of opinion and discussion are means by which it is possible to arrive ultimately at a correct interpretation of the meaning of natural phenomena, the laws of which at the present time are but vaguely comprehended.

At the outset it is well to recall that this paper deals primarily, as stated, with conditions of Southern New England and Vicinity. Conditions on this area reflecting rainfall, streamflow, weather, geological conditions and other factors are in the main quite dissimilar from those in other sections of the country.

Mr. Hoyt remarks particularly on conclusions five and six on page 363, and on paragraph five under "Rainfall Studies" on p. 364. The two conclusions to which Mr. Hoyt takes exception necessarily are based on analysis and comparison of recorded observation, and the true answer is not possible until that long period of record has elapsed which Sir Napier Shaw* in his discussion of rainfall "Normals" so aptly characterized as "something of a chimera" for which "no living meteorologist can afford to wait for its realization."

Mr. Hoyt's third disagreement is of a somewhat different character and relates to differences of opinion based on personal experience and observation. A clear cut decision on this question may never be reached by equally reliable and competent observers. With equally long and reliable rainfall and run-off records, there can be no question but that the latter would be used to establish the régime of the stream on the same watershed and be of prime value in studying a similar stream where only rainfall records were available.

While Mr. Hoyt takes exception to conclusions five and six of the paper (p. 363), it does not appear that he has considered these matters further in his discussion. Suffice it to say, therefore, that the rainfall critera shown in diagrammatic form on page 414 (Fig. 11) were based on the 65-year period of record from the West Hartford station and the conclusions drawn therefrom, as stated on p. 366, are held to be only generally applicable to the region of Southern New England. The immense amount of data collected and analyzed seems to present irrefutable proof of the reliability of the statements for this limited locality. In this connection it was gratifying that the results of the local study agreed so closely with the classical findings of Sir Alexander Binnie, referred to in the paper.† The dotted line on the diagram, Figure 11, represents the results arrived at in that paper which covered rainfall records from many localities throughout the world.

As to the conclusion regarding run-off reliability, the diagram on p. 431, Figure 21, delineates the data from two of the longest records of this character in the country, (Sudbury, Mass., and Croton, N. Y.). While probably in view of the method by which the records were compiled and the advance in the art of stream measurement, some justifiable criticism may now be made of these data, nevertheless, regardless of the alleged accuracy of more up-to-date methods the trend of the period is portrayed in them, which in the hands of competent workers would seem of value equal at least to that obtained in the earlier stages of stream flow measurement. Besides this, it is extremely difficult to locate short-term gaging records on the rainfall cycle, and to the author dangerous to place absolute reliance on such records; for after all, rainfall is the basic contributor to stream flow. Even assuming that rainfall records over a given area are probably not within 5 or 10 per cent., it is as well very questionable if some of the run-off records on streams in a valley of glacial drift are much closer unless there happens to be a solid rock foundation available for a weir. It would be absurd for anyone, of course, to attempt to substitute rainfall for stream-flow measurements in determination of maxima and minima run-offs, but for long-period dependability, the author is of the opinion that consideration of rainfall may not yet be discarded as of little value.

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*Vol. II, p. 172, Manual of Meteorology. †Page 412.

Rainfall and other historical data indicate that severe as was the drought period 1930–31, the minimum run-off period of record so far on the Croton watershed and probably on the Hartford watersheds as well was that of 1880–81, and that the 5-year period 1879–1883 has not so far recurred, although "what happens once may happen twice."

Mr. Hoyt's contribution of minimum discharge of rivers on the North Atlantic slope is greatly appreciated and this Association is indebted to him for the tabular statement which he has been so good as to contribute to this discussion.

J. GLASSPOOLE.*† I should like to express my appreciation of this valuable paper, which discusses problems of water supply from new aspects and should prove of service to water-engineers in this country. Mr. Saville, in a paper which is being published by this Society, has drawn attention to the marked dissimilarity in the fluctuations of rainfall experienced in this country and in New England. These differences are demonstrated in Figure 16. In England the rainfall of each of the ten years 1923 to 1932 exceeded the average, in fact during these ten years we have received as much rain as falls in eleven years of normal rainfall. The summer of 1933 was dry, although not unprecedentedly so, and the partial failure of the rains during the winter, 1933–34, called into play much ingenuity on the part of water-engineers in maintaining adequate supplies, and is causing the general public, especially in rural districts, some anxiety as to whether existing supplies will be adequate during the summer of 1934. The previous outstanding period of deficient rainfall in England occurred in 1886 to 1888, whereas in New England the corresponding period was apparently earlier, *viz.* 1879 to 1883. The question of the possibility of some sequence in the weather of the two countries is a fascinating one and emphasizes the importance of further studies of world-wide weather conditions and their interrelation.

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*Honorary Secretary of the Royal Meteorological Society, London, England. †By letter.

The method of expressing the minimum rainfall of consecutive months as a percentage of the average annual rainfall (Table 19) warrants special comment. Similar statistics have been extracted for stations in all parts of the British Isles, and it is found that the series of percentage values are similar in all cases. Minimum rainfalls expressed in this manner give a simple generalization, applicable to all parts of the British Isles and provide the best estimate available as to the extremes of rainfall likely to be experienced there in the future.

Mr. Saville. It is much appreciated that Dr. John Glasspoole, Honorary Secretary of the Royal Meteorological Society, has been willing to add to the discussion of this paper.

Dr. Glasspoole's long study of world weather conditions, and particularly those of the British Isles, makes him, of course, an authority on climatology, and such statements as he makes cannot but be received with the greatest assurance of their reliability.

In closing I should like to call attention to two errata in the paper as published:

Page 372, line 26: Read "20" not "80" per cent.

Page 447, last paragraph, lines 2, 3, 5 and 6: Omit "per sq. mile."

REFORESTATION OF NORTH ADAMS WATERSHEDS.

BY JOHN P. MILLER.*

[*Received March 21, 1934.*]

In 1921 the city of North Adams, Mass., initiated a program of reforestation of the watersheds of its water-supply reservoirs with the purchase and planting of 20 000 evergreen trees. During each subsequent year the number of trees planted on the watersheds has been at least 20 000, and in 1932, 50 000 evergreens were planted. The number of trees planted on the watersheds annually since 1921 is presented in the accompanying table. This table shows that, during the past 13 years, a total of 347 000 trees has been planted on the watersheds. Of this number, 340 000 were evergreen trees and 7 000 were locusts. The latter were planted in 1927 and 1928, for the purpose of providing future fence posts. This was made necessary by the destruction of all chestnut trees by a blight, which thus removed the local source of fence posts.

NUMBER OF TREES PLANTED ON NORTH ADAMS WATERSHEDS, 1921–1933.

Year	Number of evergreens planted.	Number of locust trees planted.	Total number of trees planted.
1921	20 000	....	20 000
1922	20 000	....	20 000
1923	20 000	....	20 000
1924	20 000	....	20 000
1925	25 000	....	25 000
1926	20 000	....	20 000
1927	20 000	2 000	22 000
1928	20 000	5 000	25 000
1929	20 000	....	20 000
1930	35 000	....	35 000
1931	40 000	....	40 000
1932	50 000	....	50 000
1933	30 000	....	30 000
Total	340 000	7 000	347 000

In 1925, the city set aside as a town forest 2 720 acres on the watersheds of Mount Williams and Notch Reservoirs. In that year, by reason of the establishment of the town forest, the Massachusetts Department of Conservation, through its Forestry Division, gave the city 20 000 trees for planting. In the same year 5 000 trees were contributed and planted by the

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* Commissioner of Public Works, North Adams, Mass.

Massachusetts Forestry Association. Since then all the trees planted by the city on the watersheds have been donated by the State Forestry Division. In 1930 an area of 4 500 acres on the Broad Brook watershed was added to the town forest and named the A. C. Houghton Reservation, in honor of the first mayor of North Adams.

The Department of Public Works has been active in its efforts to maintain the town forest in good condition. The State Forestry Division and the Massachusetts Forestry Association have rendered valuable assistance and advice in the care and maintenance of the forest.

Each year two men go over the parts of the watersheds where white pine is planted, to remove all wild currant and gooseberry bushes. By this means the trees have been kept free from blister rust. There have been very few cases of white-pine weevil, and to date there has not been any trouble from moths, or other insects in red pine or spruce. During the winter months, the regular employees of the Water Department work in the town forest, weeding out underbrush and trimming off the lower branches of the trees.

The evergreens planted on the watersheds are white pine, red pine, Scotch pine, white spruce and Norway spruce. The white pine grows very fast. It is common to find growths of 24 to 30 in. in one year, and in one instance a growth of 42 in. in a year has been noted. The spruce, on the other hand, grows very slowly. After planting this kind of tree, it seems to take about five years for the root system to get well started and for the trees to make their appearance through the meadow grass and weeds.

The Department of Public Works does not have much money to spend on the watersheds, as the City Council generally appropriates less than $1 000 for this purpose. On the other hand, the trees are furnished without cost by the State Department of Conservation. The trees are planted by contract, costing generally between $13 and $15 a thousand. This does not leave much of the appropriation to be spent for other work on the watersheds, unless a special appropriation is made.

In 1931, the City Council, at the request of the Mayor, appropriated $10 000 toward the relief of unemployment. This money was used in making improvements in the town forest. On 100 acres of the Mount Williams watershed, pine trees were trimmed and all underbrush was cut and burned. On Broad Brook watershed, eleven miles of fire line were cut and about twenty acres of land were cleared.

On December 4, 1933, an award was made by the Civil Works Administration, allowing the Department of Public Works to employ 100 men for a period of ten weeks. These men were divided into five crews of twenty men each, to work on the watersheds. One crew cut large-size hard wood for the sawmill; another cleaned up an area of poor growth so that it could be planted in the spring, and the other three crews cut fire lines. Two of the fire-line crews followed the outside line of the city property, and the third widened the trail up the brook.

The reforestation work carried on at North Adams serves several useful purposes. It tends to prevent soil erosion and turbid water. Silting of the reservoirs is reduced. The maturer trees retard the melting of snow in the spring and prolong the run-off from that source. The forested areas check the run-off in flood periods by storing in the soil part of the waters from rain and melting snow. Replacement of deciduous trees and brush with evergreens tends to reduce the color of the water, due to the smaller quantity of leaf carpet from evergreens. Furthermore, the fact that the supply is derived from a well kept, beautifully forested area produces a sense of pride in all citizens, whose good will and coöperation are so important.

DEVELOPMENT OF THE MANCHESTER, NEW HAMPSHIRE, WATER WORKS.

BY J. H. READ.*

[Read May 23, 1934.]

The first recorded attempt to establish a water supply in Manchester was made in 1844, following the burning of the town house. At this time Manchester was a town of about five thousand population; its neighbors Concord and Nashua were somewhat larger. A committee was appointed, and after the necessary surveys had been completed, they reported to the town officials that in their opinion Massabesic Lake was the only sufficient source, but that the cost of such a supply to a small town seemed an insurmountable obstacle. The citizens therefore had to content themselves with the wells, springs, and small brook reservoirs to which they had been accustomed.

The following year private enterprise attempted what the town shrank from doing. The Manchester Aqueduct Company was chartered by the Legislature. We also find that companies of the same name were granted charters in 1852 and again in 1857.

The last attempt of this sort was made by a group called the City Aqueduct Company, which was incorporated in 1865, at which time the City had reached a population of 22 000, and it must be admitted that this progressive company came very near placing Manchester in the list of municipalities with privately operated water works, along with Nashua which at this time had a works established although it numbered but half the population of Manchester. The City Aqueduct Company proposed to construct works on plans developed by Joseph B. Sawyer, a local engineer of note, and working in conjunction with a committee from the Common Council proposed to the voters that the City guarantee a seven per cent. dividend to the company on a capital investment not to exceed $600 000, the city to elect two of five directors of the company or the same proportion of any increased directorate; the city of course to be relieved of financial obligation whenever the water revenue reached an amount sufficient to pay dividends of seven per cent. per annum. This proposal was enthusiastically endorsed by the Mayor and the City Council, its many advantages being pointed out to the voters; but as so often happens under similar conditions, it was overwhelmingly rejected on the referendum vote.

Evidently the New Dealers of that day reasoned that if there was any seven per cent. to be guaranteed they had better guarantee it to themselves, for in 1871 the new regime, through a joint committee of the Council and Board of Aldermen, secured the services of William J. McAlpine of Pittsfield, Mass. to make a survey, and was empowered to make application to the

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* Assistant Superintendent, Manchester Water Works, Manchester, N. H.

Legislature for authority to enable the city of Manchester to establish water works.

This enabling act passed in 1871 created a board of seven water commissioners, the mayor to serve ex-officio, the Board of Mayor and Aldermen to elect the other six members who would draw lots to determine the terms for which the members of this original board would serve, so that the term of one commissioner would expire each year. This act also provided for a bond issue of $600 000 and authority to levy taxes to defray expenses. The City Council passed an ordinance to carry out the details of the authority thus conferred and elected the original Water Board.

It is interesting to note that at this time there were but four cities in the United States of more than 20 000 inhabitants in which water works were not in operation or nearly completed, these four being Manchester, Lowell, Providence, and Milwaukee.

The Board employed Colonel J. T. Fanning, an experienced water-works engineer, to make a report and submit estimates of cost on the many sources of possible water-supply that had been the leading controversial issue for the past thirty years, which in some respects at least is still with us.

Pending a determination of the source to be utilized, the Commission obtained permission from the Amoskeag Company to use their reservoir of 11 m.g. capacity at elevation 107 ft. above the City Hall steps, laid 4 300 ft. of 8-in. pipe and installed fifteen hydrants to afford fire protection to the central part of the city.

The following year, 1872, a public hearing was held at which Colonel Fanning presented detailed costs on supplies from the following sources: Merrimack River, Piscataquog River, Dorr, Chase, Burnham and Stevens ponds, Maple Falls Brook and Sawyer's Pond combined.

The Burnham Pond project was a proposal to conduct water from Maple Falls, eight miles northeast of the city by gravity through 25 000 ft. of 20-in. pipe to Burnham Pond, and using this pond as a distribution reservoir to deliver water to the city by means of a 20-in. pipe 12 000 ft. long. The area of Maple Falls watershed was estimated at ten square miles and the storage at 2 000 m.g. in a lake area of 400 acres and average depth of 15 ft., its surface being 223 ft. above City Hall steps and the surface of the distribution reservoir at Burnham's pond showing a shed area of 535 acres and an elevation of 188 ft.

Lake Massabesic in spite of all the stories told as to its name having been derived from some variety of Massa-be-sick, means in the best of Indian literature "the place of much water," and in as much as it was shown that this was literally true, and perhaps much weight was given to the fact that the cost of developing a works from that source was less than half the Maple Falls requirement, there is little wonder that the Massabesic choice was made by a five-to-two vote of the Commissioners.

Massabesic Lake is four and one-half miles east of the city at elevation 40 ft. above the City Hall steps; it has a surface area of 2 350 acres, or nearly four sq. miles; about twenty miles of shore line; and a watershed area of 45 sq. miles. A dam was constructed at the lake outlet, its apron, overfall and priming of cemented masonry, the distance between abutments being 100 ft. and height of overfall above surface of apron 24 ft. Water was led from the basin formed by this dam through an open canal 15 ft. deep for a distance of 1 500 ft., thence through a 6-ft. Georgia Pine penstock 600 ft. long to the pumping station (now called Low-Service Station).

The station was equipped with two Jonval class 36-in. water turbines working under a head of 45 ft. and two pairs of upright R. D. Wood pumps each with a capacity of 2.5 m.g.d. These pumps, using Lake water for power, raised the water 113 ft. into the distribution reservoir on Mammoth Road 8 400 ft. toward the city and required 7.5 gal. to put one gallon in the reservoir.

The 16-m.g. reservoir, as constructed, was of earth embankment type, interior slopes paved above the water surface with granite blocks and below with cement concrete. The exterior slopes were covered with loam and grassed. This reservoir is 2½ miles southeasterly from the City Hall, and is in excellent condition to-day, sixty years after being placed in service.

Water was first pumped into the system July 4, 1874, and we find from the records that the daily average use in this city of 25 000 people was at the rate of slightly more than a million gallons per day for the balance of that year. The system had a total of 23 miles of main pipe, 215 hydrants, and 625 services. The original distribution system was of cement-lined wrought-iron pipe, which figured $210 000 less than cast-iron pipe of equivalent size. The main pipe was laid by contract which specified the contractor should keep it in repair for three years. This obligation which proved a real one to him and to which the city fell heir, led to the decision to change to cast-iron pipe the next year and start a gradual replacement of all cement pipe in service.

In 1886, two 36-in. Risdon water wheels were installed at the pumping station to replace the Jonval wheels, and a Davidson duplex pump of 5-m.g.d. capacity was added. It was found necessary in 1893 to build a high-service system to accommodate those citizens who in increasing numbers had sought the higher places of the city for residence and insistently demanded water service. This condition had been recognized as inevitable by Col. Fanning, and each of his original plans had it in view.

The services of Marshall M. Tidd were secured to examine and report on the different projects suggested, and his plans were generally followed, when construction got underway, by the engineering firm of Rice and Evans. A steam pumping-station was built on the west shore of the Back Pond, so called, and near the north end, about two miles from the outlet which supplies the low-service station. Power for two Worthington pumps of 5-m.g.d. capacity was furnished by two Manning type boilers. A 20-in. cast-iron force main was laid to a new reservoir built on Oak Hill 19 000 ft. westerly, the reservoir being about a mile and a half northeastward from the City Hall. This reservoir of combined ledge and masonry wall with earth embankment has a capacity of 4 m.g. and an elevation above City Hall steps of 291 ft. This system was placed in operation in 1894. The first full year of operation showing a consumption of 214 m.g. against 820 m.g. for the low service.

At the turn of the century we find a city of 57 000 people, a daily average consumption of 3.2 m.g.d., about one-third of which was carried by the high service. In 1903 a Snow Holly V. T. E. pumping engine of 6-m.g.d. rating was installed at the high-service station in a new additional pump room.

A start towards electrification was made in 1911 with the placing of a 6-m.g.d. centrifugal motor-driven unit at the low-service station. These last two pumps were made necessary by increased demand on lake water for water power as the consumption increased, and a resultant lowering of the lake to such an extent that without these pumps some of the dry years would have left the city with a very serious shortage.

The wood-stave penstock was replaced by steel pipe in 1913 preparatory to an almost complete electrification of both stations in 1915–16. The mechanical pumps at the Low-Service Station were replaced by one 6-m.g.d. and one 8-m.g.d. motor-driven centrifugal pump and the old water wheels by a pair of Trump water turbines of 500-h.p. capacity directly connected to a 375 k.w. generator.

At the high-service station the Worthington steam pumps were replaced by one 3-m.g.d. and one 5-m.g.d. motor-driven centrifugal pump. A 1 000-k.w. Curtis turbine was installed and a transmission line between the stations was built, all pump-motors, generators, and transmission lines being operated at 2 300 volts. A connection was made with the local Public Service Company system.

The changes as outlined made for a very wieldy system. It will be seen that the electric pumps at either station may run from power at that station or from power from the other station as well as by means of power purchased from the local Public Service Company. Any or all pumps may be run singly or in parallel and with power from three independent sources: water power developed at the low-service station, steam power through the Curtis turbine at the high-service station or by purchased power. No material station changes have been made since.

The low-service reservoir was cleaned and repaired in 1919, the system being fed by direct pumping with the reservoir by-passed. At this time the wall was raised slightly and a coping added increasing the capacity to 18 m.g. The year 1920 finds us with a population of 78 000 and a daily average consumption of 5.5 m.g.d., one-third of which is high-service demand. Our total of mains 4-in. and larger has grown to nearly 150 miles, and the number of services to 8 500.

The decade 1920 to 1930 may be summarized generally as being used to improve the distribution system. A visit from the National Board of Fire

Underwriters in 1925 outlined projects that seemed at first hopeless of fulfillment, but every single recommendation made has been carried out, at a cost of more than half a million dollars.

An increase of thirty per cent. in high-service consumption during the first half of this decade made it imperative that something be done to assure increased storage in the near future. Accordingly in 1925 the Legislature authorized an issue of $500 000 in bonds for high-service improvement. The Board of Mayor and Aldermen however deemed it advisable to issue bonds only in the sum of $150 000, and specified that it be used for a new force main, a new river crossing, and a new transmission line between stations. This action prevented the construction of a new reservoir at that time. The new 24-in. force main from the high-service station to the reservoir via Bridge Street Extension was started in 1924 and completed in 1927, all work being done by our own forces in such time as was given us after carrying out our ordinary maintenance and new extensions. The addition of this main reduced the dynamic head of our pumps from 125 to 104 lb. per sq. in. and accordingly increased the capacity of the pumps with the same power input by nearly twenty per cent. A line of 16-in. Universal pipe 1 700 ft. long was laid across Amoskeag Bridge in 1926, to reinforce the 20-in. pipe on the bed of the river at Bridge Street. The balance of this bond issue was used in 1929 to build a 33 000-volt transmission line between pumping stations.

Although the census of 1930 showed that the city had about the same population as in 1920, the high-service system has maintained a steadily increasing growth, and it was quite evident that something had to be done in the near future to enlarge this reservoir. High service has been extended into surrounding towns as well as into many sections formerly supplied by low service, and inasmuch as the high service reservoir might be called upon at any time to supply the demands of the whole city, or be seriously depleted by a major leak in one of the river crossings, or by conflagration demand, no difficulty was encountered in convincing everyone concerned that additional high-service storage was imperative.

Last fall a grant was secured from the Federal Government through the Public Works Administration, a bank loan of $150 000 made and construction started on a new 17-m.g. reservoir adjacent to and of course at the same elevation as the present high-service reservoir, on a site selected by Mr. Shaw.*

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* See this issue of the JOURNAL for description of this work.

I have endeavored to keep as free of statistics as a paper of this nature will permit, but feel that the following figures will be of interest.

All figures are as of January 1, 1934.

Financial

Cost of construction of works to date...	$4 220 572.70
Bonded debt	$236 000.00
Cash on hand	$56 718.83

Distribution System

Miles of main pipe (all cast iron)	180.16
Hydrants	1 203
Gate valves	2 132
Services	10 787
Meters (96½ per cent. metered)	10 407

Pumping

Daily average — gal.	4 840 000
Daily average per capita (78 000) — gal.	62

67 per cent. of all water pumped by water power.

Land Ownership. 2700 acres, on which there have been planted, beginning in 1913, nearly one million three- and four-year old pine transplants.

In closing I want to express my regret that custom makes necessary the elimination of the many names of revered citizens who have contributed so much to the services of their city in the development of the Manchester Water Works.

MANCHESTER'S NEW DISTRIBUTION RESERVOIR.

BY PERCY A. SHAW.*

[Read May 23, 1934.]

These notes cover in a general way the need for additional reservoir capacity, the proper size of the reservoir, the selection of the site, general features of the design, and the arrangements for the construction of the reservoir.

Mr. Read has brought out in his paper published in this issue of the JOURNAL certain facts bearing on the need and general design of the new high-service reservoir. These include the description of our double system of supply, which is almost as separate as if we were supplying two distinct cities. Another is the increasing size and consumption of the high-service district. This growth, while the consumption of the remainder of the city is declining, is due partly to the fact that the high-service district covers most of the outlying sections of the city; and partly to the fact that, as modern plumbing requires better pressures, section after section of the older part of town has been put on high service. Another feature bearing on the high-service reservoir, is the distance of our supply from our distribution system, and the fact that all the water has to be pumped.

Purposes of a Distribution Reservoir. The purposes of a distribution reservoir are to supplement pumps and supply mains and to equalize pressures. A distribution reservoir supplements the pumping system in two ways, first by reducing the capacities required and second by insuring against interruption of service which in turn reduces the amount of duplication required.

The maximum rate of domestic and manufacturing consumption is probably three times the average rate. Fire consumption may be as high as five times the average rate of consumption of the entire system. Distribution reservoirs greatly reduce the amount of emergency equipment which it is necessary to keep on hand ready to operate. Distribution reservoirs also provide insurance against breaks in force mains, river crossings, and against fire or other major trouble at pumping stations.

Such additional uses as additional purification, temporary treatment by chemical methods, and the like, do not apply fully in the Manchester system because we have some distributing areas fed from our pumping mains before they reach the reservoirs.

Present Distribution Reservoirs. The low-service system with an average daily consumption of 2.8 m.g.d. is provided with a 16-m.g. reservoir. This is a very fine structure built in 1872 and still in excellent condition. The high-service system, having a consumption of 2.1 m.g.d., is provided with a reservoir having a capacity of 3.5 m.g. This is about one day's maximum supply for this service and insufficient for a possible conflagration. It must be borne in mind that while the smaller high-service reservoir could be used to stand by the low-service distribution, the larger low-service reservoir cannot stand by the high-service system.

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*Superintendent and Engineer, Manchester Water Works, Manchester, N. H.

Capacity Needed. We estimate that the maximum daily draft on our high-service reservoir, which is likely to occur at the present time due to a combination of domestic and fire requirements, would be about 9 m.g.d. Authorities agree, however, that with a supply pumped from a distance, a distribution reservoir should be provided having a week's normal consumption; provided such a reservoir can be obtained without unreasonable cost. Because of future needs and the small additional cost for a somewhat larger reservoir, we have established the proper amount of storage in high-service reservoirs at a total of 20 m.g., or 16.5 m.g. in addition to the present 3.5-m.g. reservoir. This capacity would supply the high-service system for the maximum week at the present time, or provide water for the entire city for three days. It allows for a considerable growth in the size of the city. Doubling the size of the reservoir would not increase the cost more than about one-third. In a sense, it simply means cutting a reservoir through the middle, pushing the halves apart and inserting sides and bottom for an additional length.

Location Selected. Keeping in mind the purposes of distribution reservoirs, it is obvious that they should be located as near the center of distribution as possible. It is seldom that a location in the center is available. As our distribution system is situated on both sides of the Merrimack River, and the west side is fed by mains crossing on bridges or under the river bed, it is clear that the ideal location for an additional high-service reservoir would be on the west side of the river. No site of sufficient elevation is available within a reasonable distance. The nearest site being Shirley Hill four miles from the center of the high-service distribution system. Another site considered was equally far to the east and only about half-way in from the lake to the city.

Manchester is fortunate in including Derryfield or Oak Hill, having a sufficient elevation, on the northeast edge of the high-service system. It is here that the present high-service reservoir is located.

It was decided to place the new reservoir near the present one. Using this site affords the advantage of easy and economical connection to the present reservoir and to the distribution system, and makes the operation of the two as a unit easy. The site on Oak Hill was secured from the owners (The Amoskeag Manufacturing Company and Mrs. Nora K. Jones) by the President of the Water Board (Mr. J. Brodie Smith) without cost to the city.

Type of Reservoir. The level of the present reservoir naturally fixes the elevation of the new reservoir. At the elevation required, only rather steep side-hill sites were available. At the site chosen the slope of the ground surface is at a rate of about ten per cent which has proved reasonably satisfactory for our purposes. About twenty-five test pits were dug in the area under consideration to determine the condition of the soil, the depth of ledge, and the best location for the reservoir. In determining beforehand the conditions which would be met, photographs of the excavation for the existing reservoir and the open face of a large quarry a short distance north, were used to advantage.

Ledge rock occurs within three or four feet of the surface along the top of the reservoir site but slopes downhill at about twice the rate of the ground surface. This means that a reservoir of a reasonable width for the capacity required would be located partly in ledge and partly in earth. While it seemed certain that with land available at reservoir level some form of embankment would prove the cheapest structure, other types of reservoir were considered. Vertical concrete and masonry walls proved to be very much more expensive than paving against the rock cut and sloping embankments. Steel tanks of large size have been developed for reservoir purposes but were found to be not only more expensive in first cost but also in upkeep. In our climate we would not consider them as satisfactory as a reservoir in the ground. Consideration of the various features of the site and the capacity required indicated that the most economical and satisfactory reservoir would result from the use of earth and rock embankment with a watertight concrete lining. Limiting the depth to about twenty feet and requiring the entire bottom to be in original ground, allowed a bottom width of about 265 ft. and required a bottom length of 420 ft. to get the desired capacity. As the ground sloped away more steeply at the south end of the site, this end of the reservoir was narrowed in order that the entire reservoir bottom might be kept on solid ground.

The use of topographic plans, test pits, and preliminary section indicated earth cut of about 30 000 cu. yd., and rock cut of about 20 000 cu. yd., which would expand to over 30,000 cu. yd. of rock fill. As the earth excavation would be insufficient for the entire embankment, it was used on the inside of the fill to support the concrete lining; and the broken rock was placed on the outside of the fill to provide for additional stability. The resulting section of the embankment is ample and is of a type well suited to provide satisfactory drainage.

General Features of the Design. The reservoir being partly in earth and partly in rock complicates the design, as it makes necessary detailed designs for the earth section, for the rock section, and also, most important, for a transitional section from earth to rock. In this latter section it was necessary to provide for a slight uneven settlement in the foundation.

As the water is derived from a surface supply and as there is slight danger of contamination at the reservoir, it was decided to build an open reservoir. Dispensing with a cover eliminated one of the major items of cost. Having an open reservoir, however, creates a problem of taking care of large temperature variations and of heaving by frost. Jack Frost is the worst enemy of civil engineers in this climate. The possibility of the need of a cover for the reservoir later on was kept in mind when working out the design.

Expansion and contraction are provided for by a system of joints in the lining. We have attempted to eliminate heaving by frost by using a hand-placed rock fill under the upper portion of the concrete lining. Speaking in general, we have depended on the stability of the rock cuts and embankments to withstand the water pressures, and we have attempted to design a concrete lining or paving which will be watertight. In order to make this lining watertight, comparatively thin concrete slabs of high-quality concrete and well reinforced have been provided with a very carefully worked out system of joints. Under this concrete lining, a sub-drainage system has been provided to carry away ground water and any leakage or seepage through the lining.

Connection to System. The new reservoir will be connected to the old reservoir and the distribution system by interconnection of both sets of inlet and outlet pipes so that almost any possible trouble with valves and connections can be taken care of without placing either reservoir out of service. The system of connections also provides for the proper flow of water through both reservoirs. The inlet design for the new reservoir is a result of experiments to determine the proper size of the inlet pipe and openings through which the water is admitted to the reservoir. The experiments were made with wrought-iron pipe and fittings on a scale of one inch to the foot.

Estimated Cost. Before plans and specifications were prepared, it was believed that the reservoir would cost in the neighborhood of $300 000. After preparing plans and specifications and before letting the contract, the engineer's estimate was $210 000. The contract price bid is $153 000. We expect that the final cost including extras, work done by the Water Department and engineering, will not exceed $165 000. The work was let on the unit-price basis. It allows for variations in quantity without the need of any additional bargaining. Concrete prices do not include cement which is paid for separately by the barrel and furnished by the contractor.

Financed in part by Public Works Administration. The contract was let under Public Works Administration rules and regulations. Common and skilled labor prices stipulated by the Federal Government were included in the contract. There were also included intermediate rates for semi-skilled labor which were previously agreed to by the State Public Works Administration Engineers. Common labor and skilled trades were defined in accordance with the established custom in the city.

We have signed a grant agreement with the Federal Government and are trying to conform to the rules and regulations laid down in that agreement. The city rejected the loan which had been approved; this was due to complications in city financing, long-time control of water-department operations by the Federal Government and other factors introducing delay in getting the work started. The amount of the grant received will depend on the decision in Washington as to what the phrase "thirty per cent of cost of labor and material" means. We think it means the cost to the city and should be based on our unit prices, but someone in Washington has said that it means thirty per cent. of payrolls, plus cost of material at point of manufacture, such items as freight, equipment, contractor's overhead and profit as well as engineering being excluded. We expect to receive somewhere between 18 and 25 per cent. of our total cost from the Federal government.

Construction. The contract was let on October 25, 1933 to the C & R Construction Company of Boston. Although it was late in the year, construction was started with the purpose of providing as much employment as possible. Before shutting down for the winter on December 30, 1933, the site was stripped, about half of the earth excavation was completed and the outlet chamber and piping were started. When work was resumed in April, 1934, there was over six feet of frost in the embankment, and permission to place additional fill was only recently granted.

The engineering for the project has been under the supervision of the author. Plans and specifications and contract were prepared at the Water Works office. Mr. Bernard R. Fuller is Resident Engineer for the construction.

HISTORICAL SKETCH OF THE WINCHESTER, MASSACHUSETTS, WATER WORKS.

1873–1933.

BY E. C. SANDERSON.*

[*Received February 15, 1934.*]

Sixty years ago, the construction of the Winchester Water Works was begun, and the water began to fill the North Reservoir on December 5, 1873, but owing to the partially completed state of the dam, it was not deemed advisable to fill the reservoir until the following year. During 1874 pipes were laid, and water was turned on to the piping system on September 20, 1874.

The reservoirs were created by the construction of dams so that certain natural basins could be used for the collection and storage of water. They are three in number, known as the North, Middle and South Reservoirs.

The watershed tributary to the reservoirs is remarkable in that there is not a house upon it.

The reservoirs are so located that pumping is necessary for a limited portion of the town, the larger part being supplied by gravity.

The area of the watershed is about 812 acres divided as follows:

	Acres
Watershed on State Land	367.03
Land area owned by the town around the reservoirs including right of way to Main Street	246.77
Area of Reservoirs when full	198.02
Total	812.00

The area of the reservoirs when full is about as follows:

	Acres
North Reservoir	59
Middle Reservoir	58
South Reservoir	81
Total	198

The area of the watershed (land surface) is distributed as follows:

	Acres
North Reservoir	258
Middle Reservoir	134
South Reservoir	222
Total	614

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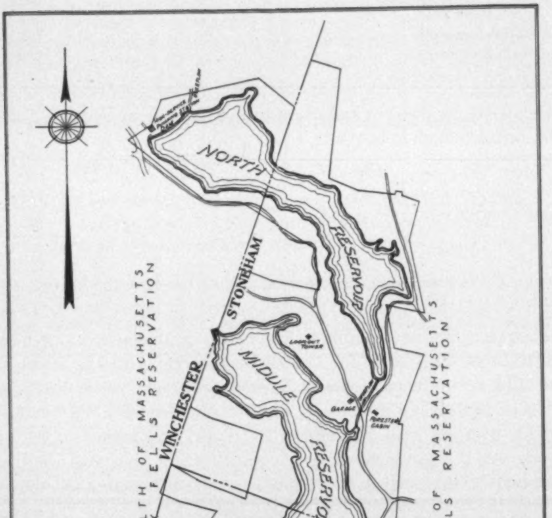
*Chairman, Water and Sewer Board, Winchester, Mass.


NORTH RESERVOIR
MIDDLE RESERVOIR
SOUTH RESERVOIR
THE GEM
STONEHAM
WINCHESTER
MEDFORD
COMMONWEALTH OF MASSACHUSETTS
MIDDLESEX FELLS RESERVATION
COMMONWEALTH OF MASSACHUSETTS
MIDDLESEX FELLS RESERVATION
LOOKOUT TOWER
GARAGE
FORESTER'S CABIN
GATE
SLUICE-WAY
OVERFLOW
DAM
OVERFLOW
WINCHESTER RESERVOIRS
SCALE OF FEET
1000
1500
2000

The reservoirs when full contain 993 600 000 gallons of water, distributed as follows:

	m. g.
North Reservoir	255.9
Middle Reservoir	187.6
South Reservoir	550.1

It was estimated by the early engineers that the watershed would yield a million gallons per day per square mile and that the safe draw-down of the reservoirs would be as follows:

	m. g.
North Reservoir — 10 feet or	159.0
Middle Reservoir — 7 feet or	118.6
South Reservoir — 10 feet or	233.6
Total	511.2

The cost of the reservoirs and land according to the Auditor's report of 1905 was $262 108.64.

The first account we are able to find of any public action taken in regard to the introduction of water for domestic purposes into the town is in the record of the town meeting held Tuesday, November 8, 1870, when a committee of nine was appointed. This committee made a partial report at the town meeting held November 27, 1871, and asked to be, and was discharged. At the same meeting a committee of five was appointed by the chairman, "to investigate and report, as soon as practicable, the question of supplying the town with water," this committee was also "empowered to employ assistance and make examinations at the expense of the town." At the town meeting held March 25, 1872, this committee made a written report to the effect that it had examined.

First — "The Holly System, and was of the opinion that it was "not available for Winchester."

Second — The Winter and Wedge Pond source, and that it was then endeavoring to secure the passage of an Act of the Legislature, enabling the town to take water from this source.

Third — That it had conferred with the towns of Arlington and Woburn. The Committee says "Both towns seem disposed to supply us, but on what terms we cannot tell; neither of the towns being in a condition to give them."

On August 3, 1872, a town meeting was held and a committee of five was appointed to investigate the whole subject of water supply and the cost of construction and to report to the town. Part of the Committee's report follows:

> It was determined to ascertain whether either Charlestown, Arlington, or Woburn, could furnish the town with a supply of water on such terms as would be advantageous and also to investigate all other possible opportunities available for the town to supply itself.
>
> Previously to the appointment of the Committee, the town had procured and accepted an act from the General Court, authorizing the taking of water from Winter

and Wedge Ponds. During a discussion relative to the features of the water supply from the ponds named, a member of the Committee suggested the watershed along the easterly line of the town, a portion of which is known as Turkey Swamp, as possibly of sufficient height to supply the inhabitants by gravity.

A meeting of the Committee was immediately arranged to perambulate the streets of the town, with Mr. George H. Norman, of Newport, R. I. — a man of very large and varied experience in matters pertaining to waterworks,— to form some judgment as to whether pipes could probably be laid without much rock cutting. Accordingly, on the 2nd day of September, the Committee and Mr. Norman met, and during the afternoon a visit was made to the high land overlooking a large part of the valley referred to. Mr. Norman's practical experience enabled him at once to say that he thought there might be a square mile (640 acres) of reliable watershed, and made the remark, that if that quantity of land was available, there was no possible doubt that a million (1 000 000) gallons per day coud be depended upon, provided the water could be retained by suitable artificial dams. He also strongly urged that a reliable survey of the premises should be made.

The Committee determined to cause a proper survey to be made of the watershed of Winter Pond, and also of the territory on the east side of the town, just described. At a meeting held October 5, the Committee by vote authorized the engagement of the services of Mr. Walter H. Sears, Civil Engineer, to make the proposed surveys. They were entered upon at once and prosecuted with great industry, and the field work was completed before the winter's snow seriously interfered with it, the last of the work being done while some snow was on the ground.

The result of the survey brought to light the facts that Winter Pond could not be depended upon as a source for a sufficient supply, and that source was dismissed; also that Wedge Pond, although yielding an ample quantity, was contaminated by the drainage of the streets of the town, and consequently its waters would become more and more impure as the population of the town should increase.

The water of either Winter or Wedge Ponds would have to be pumped; whereas the supply on the easterly side of the town could be so ponded by artificial dams (at moderate expense) that a supply for at least 20 000 people could be procured by gravity. This water is of great purity, there being nothing to contaminate it on the land nor in the air above. The Committee became so interested in this new-found supply,— especially in the fact that it can be delivered by its own gravity to a height at least 100 feet above the rail track at Main street crossing,— that they determined to ask the Legislature, then in session, to grant an act authorizing the town to secure the territory for the purpose of a water supply.

At the town meeting held March 24, 1873, it was voted to accept the Act of Legislature giving the town the right to establish a water system and elect three Water Commissioners.

At a town meeting held August 2, 1873, it was voted by the town to instruct the Water Commissioners to make no further contracts until the adjournment of the town meeting and that the Water Commissioners confer with the authorities of the Town of Woburn and ascertain the lowest terms upon which the Town of Winchester could be supplied with pure water by said Town of Woburn and said Committee to report at the time to which this meeting shall be adjourned. On November 4, 1873, a report was made in regard to taking water from Woburn, and, since it decided that it was not feasible the Commissioners were authorized to proceed with the work. Meantime, the Commissioners had let a contract to build the North Dam and on September 6, 1873, the work was started. The dam and reservoir were completed in September, 1874. During this time pipes had been laid in a number of streets in the town and on September 20 water was turned on. There was no charge made for water until November 1, 1874. The first Water Registrar began his duties November 1, 1874. Mr. William T. Dotten was appointed Superintendent the same year and served the town until his death in 1925 making a continuous service for 50 years. At his death his son, Mr. Harry W. Dotten, was elected Superintendent and is now serving the town. In the past 60 years the Water Works has had only two Superintendents.

Soon after the completion of the Water Works there arose a demand for water by the citizens living on the east hill which could not be reached by the gravity supply. In 1885, a high service line was built in Highland Avenue and a basin blasted out of the rock at the present site of the North Tank. The water was pumped by a windmill situated at the North Dam. This arrangement did not prove adequate and a steam pump was installed in 1888. A new iron tank was erected on the hill near the North Reservoir in 1898. This tank is still in good condition and will serve for many years.

In 1888 a new house was built near the North Reservoir for the Superintendent. In the basement of this house was constructed a pumping plant to replace the windmill. It was not put into active operation until 1892. The present pump-house was built in 1898. It was equipped with a kerosene engine and pump which did duty until 1915 when it was replaced by an electric pump. In turn this pump has been replaced with a modern pump with larger capacity and higher efficiency.

As the water pipes were extended through the town and more people became water-takers, it became evident that the North Reservoir would not supply the demand and at a town meeting held November 20, 1880 "the Water Board was instructed to proceed, as speedily as prudence would permit, to purchase all the land for the South Reservoir and to commence the building of the same." The Water Board procured the services of Walter H. Sears who made the surveys for the whole system. It was decided to build a dam of earth similar to the one at the North Reservoir with a cement core in the center and to prepare a basin for water. This proved to be a very large undertaking for the town, but after 10 years, the work was completed. There were held many town meetings and a great deal of oratory was expended on the project but the Water Board at that time knew enough not to ask for the full amount of money necessary to complete the work at one time but fed it to the citizens by degrees and eventually completed the work. When the reservoir was completed the northern end was very shallow and, on advice of the State Department of Health, a dam was built dividing what we now call the South and Middle Reservoirs, in that way raising the level of the water in the shallow area. The shores of the South Reservoir are very steep and rocky and there has been very little trouble with the quality of the water from the South Reservoir. The Middle Reservoir for the first few years gave much trouble with bad-tasting water, but for the last 15 years the water has been of excellent quality. In 1893 the South Reservoir was connected with the town system at Symmes corner thus making a very flexible system, as either the North or South Reservoirs can now be used to feed the whole town and the Middle Reservoir can feed either the North or South Reservoirs.

In 1903 there developed a demand for water on the west side hills which could not be supplied from the gravity system, so a booster pumping station was built on Myopia Road near Cambridge Street and a wooden high-service tank built on Andrews Hill which was replaced by a cement tank at a higher elevation in 1912. This station is equipped with two electric pumps. It was originally equipped with an oil engine and pump, but the neighbors objected to the noise and it was changed.

In 1894 the first survey of the streets was made, and while the engineers were at work it was deemed advisable to have the watershed resurveyed and the amount of water in the reservoirs definitely determined. A very valuable piece of work was done, and it has been of great help in keeping records of the water supply.

In 1880 the Water Department commenced manufacturing its own cement-lined pipes. It had a plant in back of the old Water Works Shop on Vine Street and for about five years, manufactured all the small pipe that was used in the town. The pipe consisted of an outside casing of wrought-iron riveted together and lined with about an inch of cement. This pipe proved very satisfactory but has been gradually removed as the town grew and larger pipes were required. There is very little now remaining in the streets.

In reservoirs where the basin has not been cleaned of all stumps, loam, and vegetable matter, it takes from 10 to 12 years to reach the same quality of water as in a basin that has been cleared to gravel and in 1879 much trouble was experienced with the water in the North Reservoir. Different authorities were consulted and it was ascertained that the quality of the water was safe for drinking but the taste was very disagreeable. Suggestions were made that a filtering plant be built at the base of the dam, that water be pumped from Mystic Pond, or a connection be made with Woburn, but nothing was done and when the winter came on, the situation cleared up. The next year the quality of the water was good again. We now know the trouble with the water came from algae. In 1932 algae developed but were discovered before they reached the piping system and the reservoir was shut off and treated. The State Department of Health examined the water in the reservoirs about once a month for microscopic organisms and bacteria.

When the North Reservoir was placed in service 115 black bass weighing from three-quarters of a pound to two pounds each were put into the reservoir. In 1880 it was decided to grant permits for fishing. A number of controversies over this matter developed during the following years. From time to time fishing was allowed and abuses developed and the privilege was rescinded until, by vote of the town, the State Department of Health formulated rules and regulations for the protection of the water and among them recommended that fishing be prohibited. In town meeting the regulations were accepted and became part of the regulations of the town. The present Water Board has had many suggestions in regard to allowing citizens to fish, but as transportation facilities from Boston come so near our reservoirs it would be impossible to properly protect the reservoirs if fishing was allowed.

As the town of Stoneham grew a number of houses were built on the watershed of the North Reservoir which extended almost to Stoneham Square, and the cesspools of these houses became a menace to the water supply. In 1899, on advice of the State Department of Health, all the land north and including Dykes Meadow was cut off from the watershed and in this way the town lost about one-third of the North Reservoir watershed.

In 1905 the Water Board recommended the general use of meters as a way of conserving water. In 1911 the Board felt the water supply had reached its limit as the reservoirs had not overflowed for some time. Mr. A. E. Whitney, who controlled all the water rights on the east side of the town and was much interested in Winchester, released the right to the water from Mollie's Brook which flowed into his mill-pond. The water was then diverted to the South Reservoir. Twenty-five acres of land were in this manner added to the South Reservoir watershed. As more meters were installed the demand on the reservoirs lessened and up to the present we have had an ample supply of water. The town is now completely metered.

On October 22, 1906 the Board of Sewer Commissioners was abolished and the duties were relegated to the Water Board.

When the Metropolitan Park Commission established a playground near the North Reservoir more people came from Boston and surrounding towns. The problem of properly guarding the reservoirs developed and after consultations with the Metropolitan Park Commission it was decided in 1912 to lease the reservoir lands for care and control to them. This did not prove to be a satisfactory arrangement as they were only interested in the park as a recreation center. In 1917 the Water Board felt that this created a menace to the water supply and, by vote of the town, the Water and Sewer Board cancelled the agreement with the Park Commission and an inspector was appointed to report conditions to the Board. In 1918 a forester with police powers was appointed to take charge of the reservoir grounds. He was furnished with a horse, and a log cabin was built for headquarters.

During the winter of 1918 fuel was very high and scarce. It was suggested that the Board authorize the cutting of trees bordering the reservoirs by the citizens for fuel. This the board granted and the work was started. It was decided to plant pine trees on this cleared land so that as they increased in size they would act as a barrier to keep the leaves of the hardwood trees from blowing into the reservoirs thus affecting the color of the water. Since then, a systematic planting of pine trees has been carried on under the advice of the State Department of Forestry. In 1927 the work of planting trees was completed at a cost of $50 000. About 380 000 of various kinds of pine were used. The hardwood trees are being gradually thinned out as the pine trees make a good ground cover.

During the last few years much work has been done on the watershed. All low and marshy places have been drained so that the water will flow quickly into the reservoirs and not become colored by standing or lost by evaporation. This has proved its worth as undoubtedly the amount of water recovered from the watershed has been increased.

In 1924 the residents of the Dunster Lane section, which lies at the extreme westerly end of the town near the Arlington line, petitioned for water. As they were a long way from the Winchester supply, arrangements were made with Arlington to supply this district. In 1925 Winchester laid the mains and is purchasing water from Arlington to supply about 25 customers.

In 1929 and 1930 the reservoirs were drawn very low on account of dry weather, and the Board asked the town to appoint a committee to investigate all matters pertaining to the Water Department and also means of increasing the water supply. The excessive rain in the fall of 1932 almost filled the reservoirs and the spring rains of 1933 caused them to overflow. The Water Board has had the water system of the town connected with Arlington and Stoneham, who use the Metropolitan water supply, and the City of Woburn, having an ample supply of its own. Engineers have made a careful survey of the water works and state that the consumption of water about equals the supply and that in a few years the town will be obliged to enlarge the supply. The Water Department is equipped with all the necessary instruments for keeping accurate records of the water supply.

In 1926 a large real estate development was started on the high land off Highland Avenue in the southerly part of the town known as Symmes Park. It soon developed that there was not an adequate water supply for fire purposes, and the Water Board presented two plans to take care of this condition: one, to build a new feeder pipe from the North Tank, a distance of about 9 000 ft., at an approximate cost of $50 000; the other plan was to erect a storage tank at Symmes Park at a cost of $20 000. The Finance Committee recommended to the town the storage tank, and in 1929 the town unanimously voted the appropriation, and it was built.

In 1929 a new shop was purchased on Lake Street. This shop and garage is modern in every particular and is a great asset to the department.

There has always been a leak at the base of the North Dam, and in 1930 a well and pump-house were built to recover this leakage which amounts to about 40 000 gallons per day and is pumped into the east high service.

In 1930 the Sewer Department was consolidated with the Water Department under one superintendent. This was done so that the departments could be more economically operated.

Many well known engineers and business men have given freely of their time to the town to carry on the Water and Sewer Departments. This has been reflected in its efficiency. Few municipally owned plants can show such a good financial record as Winchester.

The Water Works as of Today.

The Winchester Water Works consist to-day of the three reservoirs situated in the Middlesex Fells in the towns of Winchester and Stoneham and in the city of Medford.

The North Reservoir supplies the North and East Sections of the Town, and the East High Service. The South Reservoir supplies the South and the West Sections of the Town, and the West High Service. The supply from these reservoirs is usually divided in the centre of the town, but the load on the reservoirs can be adjusted by changing the gates. The South Reservoir is 11.6 ft. higher than the North Reservoir when they are both full. In case of a bad fire the division gates are opened and both reservoirs feed the system. A water department man attends all fires to look after the interests of the Water Department.

The Middle Reservoir is between the North and South Reservoirs. It has a higher elevation and can flow into the other reservoirs. It is a storage basin and is used only when needed. It cannot be connected with the water mains.

There is a small district in the extreme westerly part of the Town for which water is purchased from Arlington. We are now building about one mile of 10-in. water main to connect this district with our West High Service. This work is being done with C. W. A. Funds. Uncle Sam is supplying the labor and a small part of the water pipe. The town is supplying the balance of the pipe, hydrants, etc., also the foreman and pipe-layers. The expense is about evenly divided.

There are no houses on the watershed of our reservoirs except the foresters cabin, garage and fire-tower, all owned by the town. The area of the watershed is 614 acres of which the town owns 247 acres. The balance is in the Middlesex Fells. The Town has the sanitary control of the entire watershed. The area of the water in the reservoirs is 198 acres, making a total area of land and water, of 812 acres.

The watershed is steep and rocky. It is completely forested with a mixed growth of trees. Two-thirds of which, or about 375 000 are coniferous trees of various kinds which were planted by the town. For fifteen years we have been planting four-year transplants. The other third are hardwood trees of various kinds.

We believe that the advantage derived from changing a hardwood growth to a mixed growth lies principally in the fact that the thick foliage of the pine trees retards evaporation in the summer time and delays the melting of the snow and ice in the spring, thus regulating the run-off of the watershed. The needles of the pine trees do not blow into the water of the reservoir and discolor it.

Where there is a mixed growth and a fire occurs, the land will not be entirely denuded of vegetation as would be the case with an all pine growth and the land will not be subject to excessive evaporation until new trees can be grown.

The pine trees are being attacked by a number of insects and diseases, among them the pine weevil, blister rust and the English pine-shoot moth. We consider the English pine-shoot moth the most dangerous. The forestry work is in the hands of a forester who has charge of the workmen and also acts as a police guard. The reservoirs are patrolled with an automobile equipped for fighting brush fires. There is also a fire tower which is used in dry weather as a lookout.

The Board decided that it should have some authority on forestry to look over the work on the watershed of the reservoirs. Mr. R. T. Fisher, Director of the Harvard Forest, came to Winchester on a number of occasions and gave careful consideration to the work with our forester. He presented a plan for the forestry work which the Board voted to carry out. (See p. 296).

HARVARD UNIVERSITY.
HARVARD FOREST.
PETERSHAM, MASSACHUSETTS.

Town of Winchester,
Water and Sewer Board,
Town Hall, Winchester, Mass.

Gentlemen: In recommending a policy for the handling of forest growth on the watersheds of the Winchester reservoirs, I am considering the purposes which the tract is to serve, the type of forest which is most likely to fit the natural conditions, and finally the excellent plantations of pine which have already been established. Presumably the Town wants a forest that is permanent, most economical to maintain and protect, beneficial to soil and drainage, and satisfactory for park purposes. Experience has shown that the best type for such purposes is a mixed forest of varying age, such as the hardwood with hemlock and some pine which grew naturally in the locality. Such a forest generally means a porous and fertile soil, maximum resistance to fire, disease, and insect pests, and the opportunity for the management to keep it permanent by releasing younger trees from time to time as the old ones fail and have to be removed.

In comparison with this kind of forest a stand of pure pine, especially one where all the trees are of approximately the same size and age, has drawbacks. Fire is difficult to control and almost certain to kill all the trees. The stand is comparatively short lived; and when all the trees become old and mature, there being no younger generations on the ground, a new forest has to be started. A dense pure pine forest tends also to reduce soil fertility by building up a heavy layer of needles and duff which decomposes very slowly and sometimes causes the soil to become unduly compact. As to the relative permeability to water of soil under pine and under a mixed forest, there is, so far as I know, no quantitative knowledge. It is true that during the growing season hardwoods transpire much more water vapor than pines of equal leaf area; but on the other hand a very large amount of the rainfall, especially in spring, summer, and autumn, does not reach the ground at all through a pine stand, part being intercepted by the thick tree tops and still more by the matted duff on the ground; all of which goes back into the air by evaporation.

On such a watershed as yours, with bed rock so close to the surface, the effect of a given type of forest on surface drainage does not seem to me so important as the considerations of health and soil improvement, permanence, ease of protection, etc., as indicated above. With so much of the hardwood on your watershed already removed and so handsome a belt of pine plantations already established, it is not practicable to secure a mixed stand except very gradually and in particular areas or patches. I would suggest that no more of the larger hardwoods be cut; that the brushing out of small hardwood and underbrush between the planted pines should be confined to the larger stump sprouts or such shoots as are threatening to overtop the pine; that in places where the plantations are thin or in poor condition any thrifty seedlings or small saplings of oak, ash, or maple should be left to grow. This latter recommendation would apply only some distance back from the shore line, since the marginal belt of conifers is useful to keep out leaves and generally too large to admit an admixture of small hardwood.

If you decide to carry out these suggestions, I should be glad to come out from time to time and consult with Mr. Shea.

Very truly yours,
(Signed) R. T. Fisher,
Director.

November 18, 1933.

We have successfully used copper sulphate for destroying algae. A boat is equipped with an out-board motor and the copper sulphate is placed in bags and drawn through the water until it is dissolved. We usually shut off the reservoir while it is being treated. The State Department of Public Health is consulted before treating, and samples of the water are always sent to it before and after treating. The treatment has been successful so far, and the trouble usually clears up in a few days. Our system is very flexible and we can supply the whole town with water from either reservoir. The quality of the water is watched very carefully; samples are taken monthly and sent to the State Department of Public Health for examination.

The distribution system consists of about 54 miles of street mains that are of cast iron, with the exception of 4 448 ft. of cement pipe in good condition, 580 hydrants and 3 097 services, all of which are metered.

The pumping equipment consists of two electrically operated pumping stations. One is for the East High Service and takes water from the north piping system and the other is for the West High Service which takes water from the south piping system. The North Pumping Station has an auxiliary pump driven by a kerosene oil engine. This pump is used for emergencies only. The West High Service Station has two electrically operated pumps and in an emergency water can be had from Arlington for this district.

There is also a small automatic pump and catch basin below the North Dam, from which are pumped about 40 000 gallons of water per day from leakage through the dam, into the East High Service.

The electrical pumps in the main pumping stations are of the centrifugal type connected with 30-h.p. motors with hand starters and automatic stops. We believe that a man should visit the pumping stations and start the pumps as a safety measure.

There are two steel water towers of about 400 000 gallons capacity at either end of the East High Service connected by about two miles of 10-in. water main. The pump is near the North Tank and the water is pumped into the piping system and equalizes between the storage tanks, insuring a good volume of water throughout the East High System. The North Storage Tank was built in 1898 and is still in good condition. The South Storage Tank was built in 1929. On the West High Service there is a cement tank of 280 000 gallons capacity. This tank was built in 1912. About ten years ago it started leaking very badly and was water-proofed by the Western Water Proofing Co. It has been satisfactory ever since.

The personnel of the Water Department consists of a superintendent, foreman, two meter men, who read and repair meters, and seven workmen. Additional men are hired when needed. A Forester who acts as police guard is in charge of the watershed and reservoirs. One man is employed all the year and extra men are hired when needed.

The main office is at the Town Hall and is in charge of the Water Registrar. There is also another clerk in this office. There is an office at the shop which is in charge of the Superintendent with a clerk. The Water

Registrar has charge of the reading of meters, billing, and keeping all accounts. There has recently been installed a new set of books, and the department is equipped with a complete set of plans of street mains and services. All services are metered.

Meters are regularly tested about every five years. The department is equipped with a modern meter-testing outfit. When new services are installed the town pays for the work in the street and the customer pays for work on private property. Our standard ⅝-in. meters are furnished free. Larger meters are charged for, but a credit is allowed for the standard meter. Money for work to be done must be deposited with the Town Treasurer in advance. The Water and Sewer Department coöperates with the Highway Department by the exchange of equipment and men.

The department has rendered a number of free services to its customers. When it develops from meter readings that an excessive amount of water has been used, the meter is immediately re-read and if it has registered right, our meter man looks for leaks and if any are found he reports to the customer. The office then writes a letter stating that there are leaks in the house and recommends that a plumber be employed to make repairs. The customer is told the amount of the bill that he will receive. In this way the waste of water is stopped and the customer is prepared for a large bill. This method stops many complaints in regard to excessive bills. If a customer complains of poor pressure a man is sent to the house to investigate and report. Usually one of two things is the matter. The service may need cleaning or renewing, or the piping may be corroded so that the water will not flow. We clean a service for a flat price of $5.00. This cleaning, usually called a punch-out, is good for a few years. A record is kept on the service card at the Superintendent's office and the ledger card at the main office of punch-outs, and when the customer complains again he is advised to have his service renewed.

The water bills are made out by the Water Department and are payable to the Town Collector. A large number of the bills is paid before a summons is sent out, which costs 20c. This summons brings in many more bills. The accounts are then turned over to the Water Department which sends out a shut-off notice. Usually about 300 customers have to be threatened with a notice. We do exactly what the shut-off notice calls for on the date set. It is understood in the town that the department insists that the water bills be paid. When a customer calls at the office and claims that he cannot pay the bill he is told to go to the Welfare Department and get a certificate and that the bill will then be adjusted and that the Welfare Department will investigate and report. This scheme works. We have never had to make an adjustment. We believe that the welfare work of the town should be done by the Welfare Department and not the Water Department. On December 31, 1933 there were only 8 overdue water bills remaining unpaid, amounting to $35.18, out of a total billing of $50 693.33. The water has been shut off from all customers with overdue water bills. Eventually most of these bills will be paid. The shutting off of the water has not been a hardship to any customer. The houses where the services were shut off are vacant; the people moved out and did not pay the water bill. We hold the owners of the property responsible for the water bills, and we do not accept tenants as customers except in the case of a reliable business concern with good credit standing.

DETERIORATION OF WATER PIPES IN BELMONT, MASSACHUSETTS, RESULTING FROM TUBERCULATION.

BY CHARLES W. SHERMAN.*

[*Received April 1, 1934.*]

The flow tests described herein were made during the summer of 1933 on pipes constituting parts of the distribution system of the Belmont Water Works, ranging in diameter from 6 to 12 in., and in age from 5 to 46 years.

Belmont is a strictly residential community, and all the tests were made between the hours of midnight and 5 A.M., when the use of water was very small. The quantities drawn for consumption through the pipes under test, during these hours, were insignificant, and no measurable variations in flow were caused by them. The section of pipe upon which a test was to be made was isolated from the remainder of the system, except at the end where it was fed, by closing valves. Then a hydrant was opened, causing a flow through the pipe. The rate of discharge was measured by a Pitometer inserted in the pipe, and approximate checks were obtained, first by the use of a hydrant pitot to determine the rate of discharge, and subsequently by examining the Venturi meter charts on which the increased rate of flow resulting from opening hydrants was clearly indicated. These figures were used only to check the Pitometer measurements, except in one run when the Pitometer was not properly adjusted and the rate of flow shown by the hydrant pitot was used. In general, the flows indicated by the three methods of measuring did not differ materially.

Elevations of points on the hydraulic grade line were determined by pressure gages on hydrants. The elevations of the gages were found by levelling from bench marks, and checked by taking static-pressure readings (at the beginning of each test run, before hydrants were opened), and noting that the static pressure at all gages corresponded closely to the elevation of the reservoir. All gages were tested before and after the experiments. In two or three cases, where there were no hydrants available at the locations desired, the pressure gages were attached to house sill-cocks. Lengths of pipe were determined by measuring on the ground over the pipe. All computations have been based upon the nominal diameters of the pipe.

All of the older pipes are of cast iron, pit cast, with the ordinary tar-dip coating. They are in 12-ft. lengths. Some of the fittings are of the ordinary water-works type, some are globe fittings, and some branches have been made with a tapping machine. The newer pipes (7 years or less in service) are spun pipes with cement linings applied centrifugally. However, the fittings are not lined. Some of the centrifugally-cast pipes are in 12-ft. and some in 16-ft. lengths.

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* Of Metcalf & Eddy, Engineers, Boston, Mass.

The Belmont Water Works were started in 1887. The water was obtained from the Watertown Water Supply Company, which had driven wells and a filter gallery near the Charles River in Watertown. At first the water was soft and practically free from iron. Whether or not it was high in CO_2 is not known. Later this water became comparatively hard, and the iron content became objectionable. Metropolitan water has been used since it became available in 1898. This is a soft water from an upland source, and it has been known for many years that pipes conveying this water tuberculate rapidly. Chlorination has been practiced for about 3 years; otherwise the water is untreated.

TABLE 1.— SUMMARY OF FLOW TESTS — BELMONT DISTRIBUTION SYSTEM
AUGUST AND SEPTEMBER, 1933.

Test No.	Size of pipe. Inches.	Kind.	Age. Years.	Velocities—f.p.s.		Hazen-Williams Coefficient C	
				Min.	Max.	Average.	Range.
3B	12	Cast Iron	9	2.46	3.68	85	81–91
2A and 3A			20	1.38	3.68	54	49–60
2B	10	Cast Iron	20	1.99	3.90	47	43–49
5			29	3.36	4.86	51	50–52
1			46	3.24	4.72	42	42–43
4A	8	Cast Iron	46	3.44	4.86	46	46–46
4B		Cleaned	46*	3.44	5.60	77	76–78
6	6	Cast Iron	44	2.39	2.68	31	31–32
8	8	Cement lined	5†	2.87	3.50	122	114–126
7	6	Cement lined	5½	3.44	10.8	120	118–124

* Cleaned 1 year before test.
† Average.

The results of the tests are shown in Tables 1 and 2. The very low coefficients of discharge for the uncoated pipes, even when in service for so short a time as 9 years, are notable. No data are available for comparison of conditions on any particular pipe at several ages, nor is it possible to tell accurately what the coefficient would be for any particular pipe if it were new. Turbulent flow caused by joints, changes in direction, branches (including hydrant branches), and valves obviously would result in a lower coefficient for a section of pipe in a distribution system than for an equal length of straight pipe without valves or fittings. It is well known that the interior condition of new unlined pipes varies considerably. Some foundries have turned out much smoother pipes than others, and centrifugally-cast pipe usually is considerably smoother than the best pit-cast pipe. Lined

TABLE 2.— DETAILS OF FLOW TESTS — BELMONT DISTRIBUTION SYSTEM.

August and September, 1933.

Size of Pipe Inches.	Test No.	Date 1933.	Time, A.M.	Velocity f.p.s.	ELEVATION OF HYDRAULIC GRADIENT AT		Drop Feet.	Length Feet.	Hydraulic Slope. S.	Disch. Coeff. C.	Location.
					Upper End.	Lower End.					
12	3B-1	Aug. 29	3:39– 3:45	2.80	262.9	251.0	11.9	2135	5.57	83	Oakley Road.
	3B-2		3:54– 3:58	3.22	249.1	233.0	16.1	2135	7.54	81	
	3B-3		4:09– 4:15	3.68	228.9	210.5	18.4	2135	8.62	87	
	3B-4		4:25– 4:30	2.46	273.3	265.4	7.9	2135	3.70	91	
									Average	85	
12	2A-1	Aug. 29	12:43–12:50	2.58	290.3	246.9	43.4	3376	13.0	49	Belmont St., Oakley Rd., Pequossette Rd., and Fairview Ave.
	2A-2		1:10– 1:15	2.71	290.0	244.7	45.3	3376	13.4	51	
	2A-3		1:23– 1:30	2.65	290.2	247.8	42.4	3376	12.5	51	
	2A-4		1:39– 1:45	1.38	309.0	296.2	12.8	3376	2.79	60	
	3A-1		3:39– 3:45	2.80	284.8	264.1	20.7	1685	12.3	54	Belmont St. & Oakley Rd.
	3A-2		3:54– 3:58	3.22	277.3	250.7	26.6	1685	15.8	55	
	3A-3		4:09– 4:15	3.68	266.2	230.7	35.5	1685	21.1	54	
	3A-4		4:25– 4:30	2.46	289.6	274.1	15.5	1685	9.2	56	
									Average	54	
10	2B-1	Aug. 29	12:43–12:50	3.70	238.6	178.1	60.5	1938	31.2	49	School St.
	2B-2		1:10– 1:15	3.90	235.5	168.0	67.5	1938	34.8	49	
	2B-3		1:23– 1:30	3.81	238.8	173.0	65.8	1938	33.9	48	
	2B-4		1:39– 1:45	1.99	292.8	261.2	31.6	2442	12.9	43	
									Average	47	
10	5-1	Sept. 1	3:24– 3:30	3.77	279.3	210.9	64.8	2287	29.8	51	Trapelo Road.
	5-2		3:43– 3:50	4.55	262.3	164.6	97.7	2287	42.7	51	
	5-3		3:58– 4:05	4.88	254.0	141.5	112.5	2287	49.2	50	
	5-4		4:14– 4:20	3.36	286.3	233.0	53.3	2287	23.3	52	
	5-5		4:29– 4:35	4.86	254.0	146.6	107.4	2287	47.0	51	
									Average	51	

10	1-1	Sept. 8	1:39– 1:45	3.24	264.2	197.3	66.9	2124	31.5	43	White St.
	1-2		2:05– 2:10	4.10	231.4	136.2	95.2	1828	52.1	41	
	1-3		2:29– 2:35	4.33	224.5	121.2	103.3	1828	56.4	42	
	1-4		2:55– 3:00	4.02	233.7	146.5	87.2	1828	47.7	43	
	1-5		3:15– 3:20	4.72	207.8	139.8	68.0	1048	64.4	42	
									Average	42	
8	4A-2	Aug. 23	2:18– 2:29	4.86	246.3	149.0	97.3	1283	75.9	46	Common St.
	4A-3		2:58– 3:05	3.44	282.2	230.3	51.9	1283	40.5	46	
									Average	46	
8	4B-2	Aug. 23	2:18– 2:29	4.86	299.5	246.3	53.2	1856	28.6	77	Common St. (cleaned pipe)
	4B-3		2:58– 3:05	3.44	310.3	282.2	28.1	1856	15.1	78	
	4B-4		4:03– 4:10	5.60	296.2	224.9	71.3	1856	38.4	76	
									Average	77	
6	6-1	Sept. 6	12:59– 1:05	2.68	306.5	87.5	219.0	3111	70.4	32	Grove St.
	6-2		1:39– 1:45	2.69	307.4	86.4	221.0	3111	71.1	32	
	6-3		1:59– 2:05	2.65	309.9	93.8	216.1	3111	69.4	32	
	6-4		2:15– 2:20	2.51	309.6	112.4	197.2	3111	63.4	31	
	6-5		2:29– 2:35	2.39	310.4	132.8	177.6	3111	57.1	31	
									Average	31+	
*8	8-2	Sept. 19	2:01– 2:10	3.06	184.4	175.4	9.0	1743	5.16	124	Watson, Gale and Douglass Rds.
	8-3		2:23– 2:25	3.28	171.3	161.4	9.9	1743	5.68	126	
	8-4		2:36– 2:40	3.50	150.8	137.5	13.3	1743	7.63	114	
	8-5		2:49– 2:55	2.87	200.7	192.7	8.0	1743	4.59	123	
									Average	122	
*6	7-1	Sept. 19	4:55– 5:02	10.8	251.1	116.7	134.4	1653	81.4	118	Elm St. and Foster Rd.
	7-2		5:19– 5:25	9.70	263.0	151.7	111.3	1653	67.3	116	
	7-3		5:35– 5:44	3.44	313.9	300.1	13.8	1653	8.85	124	
	7-4		5:49– 5:55	5.48	300.2	264.8	35.4	1653	21.4	122	
									Average	120	

*Cement lined.

pipes when new probably have always been smoother even than centrifugally-cast unlined pipes.

An attempt has been made to form a reasonable estimate of the coefficient for each pipe when new, but with the same fittings, valves, etc., as those now in existence. It is admitted that such an estimate is based largely upon judgment, and no accuracy can be claimed for it. Yet reduction in carrying capacity can be arrived at only by a comparison with the condition when new. Therefore the figures in Table 3 are presented as an approximate indication of the effects of tuberculation in these cases.

TABLE 3.— REDUCTION IN CARRYING CAPACITY OF PIPE IN BELMONT WATER WORKS, FOR VARIOUS AGES.

Size of pipe, Inches.	Test No.	Age of pipe, Years.	Estimated coefficient C if new.	Present coefficient C.	Per cent. capacity.
		Unlined Cast Iron Pipe, Pit Cast.			
12	3B	9	130	85	65
12	2A and 3A	20	130	54	42
10	2B	20	130	47	36
10	5	29	130	51	39
10	1	46	130	42	32
8	4A	46	125	46	37
8	4B	46*	125	77*	62*
6	6	44	125	31	25
		Cement Lined Cast Iron Pipe.			
8	8	5	130	122	94
6	7	5½	130	120	92

With regard to the cement-lined pipes, the data are too few to enable definite conclusions to be drawn. The deterioration as compared with the condition when new may have resulted from tuberculation on fittings and on valve bodies, and on cut ends of pipes, together with a possible slimy coating of polyzoa on the interior of the cement lining. Experience with the old-fashioned sheet-iron cement-lined pipes leads to the belief that little if any further deterioration will be suffered.

Deterioration in carrying capacity of the unlined pipes has been rapid and continuous; but there is considerable probability that the oldest pipes will suffer little if any further loss in capacity. A diagram (not reproduced herewith) showing the relation between percentage condition, as represented by carrying capacity and age, indicates that unlined pipes at various ages would have on an average the following percentages of their capacities when new:

Age—Years.	Per cent. Capacity.
10	62
20	40
30	34
40	31
50 or more	30

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* Cleaned 1 year ago.

Supplement (*July 1934*). In addition to the tests reported in the preceding, one was made upon nearly 3 000 ft. of 10-in. compound pipe in Belmont Street. Part of this pipe was unlined cast iron and part was cement lined. The unlined pipe was 7 years and 10 years old, and the lined pipe was 6 years old.

In May 1934 a single test of more approximate character was made on this pipe, observing the pressure losses at each hydrant, the pressures being noted at 13 points in all. The work was done between 8 and 10 P.M. Rate of flow was determined by noting the excess indicated by the Venturi meter during the test, as compared with the rates observed before and after the hydrant was opened. But one rate of flow was used. Elevations of gages were not determined, but friction losses were assumed to be shown by the reduction in pressure while the hydrant was open as compared with that observed before and after inducing the flow. That the final result was reasonably accurate is indicated by the fact that the coefficient found for the whole length of pipe was the same as that found in 1933.

The results of the test are as follows:

Rate of flow 2.07 m.g.d. Velocity in 10-in. pipe, 5.86 ft. per sec.

Section I. Unlined C.I. pipe, 7 years old. Length 540 ft. Loss of pressure 6.4 lb. per sq. in., $C = 83$.

Section II. Unlined C.I. pipe, 10 years old. Length 910 ft. Loss of pressure 20.4 lb. per sq. in., $C = 63$.

Section III. Cement lined pipe, 6 years old. Length 1 690 ft. Loss of pressure 9.6 lb. per sq. in., $C = 121$.

It will be noted that C for the 10-in. cement-lined pipe corresponds closely with that for the 6 and 8-in. pipes. In the unlined pipes the coefficients are less than would have been expected for pipes but 7 and 10 years old.

SANITATION OF WATERSHEDS.

BY A. D. WESTON.*

[*Read May 23, 1934.*]

Of the 355 cities and towns in Massachusetts, 239 are supplied in whole or in part with water from public supplies. About 50 per cent. of this number are from surface sources, 40 per cent. from ground sources, and 10 per cent. from both surface and ground sources.

The ground-water sources of supply are chiefly from dug or tubular wells in glacial deposits where the soil acts as a natural filter. Such sources are in most cases sufficiently remote from pollution as not to constitute any considerable problem in watershed sanitation.

The surface sources are from lakes, or ponds, or from impounding reservoirs on streams. In connection with the sources of water supply of this class there are many problems of watershed sanitation, viz., problems relating to the disposal of sewage of those who may reside on the watershed, use of the land for agricultural and pasturing purposes, lumbering operations, and use of the watershed for recreational purposes, such as boating, fishing, hunting, camping and picnicking. Massachusetts has but one water supply where the water is taken from a stream polluted by the disposal of sewage from municipalities and industrial plants. Although that supply is filtered through slow sand-filters and chlorinated, the Department has recommended that a new and safe source of supply be secured.

In Massachusetts a pond or lake having a natural area of 10 or more acres is a Great Pond, and by our colonial laws is set aside as the property of the Commonwealth with free fishing and fowling privileges to the public. However, the Legislature has the right to grant the use for public water-supply purposes of such Great Ponds as it may wish, but up to the present time only 196 of the 1302 Great Ponds of the State have been given over to this use.

All public water supplies in Massachusetts are established by act of the Legislature. These acts designate the sources of supply to be used, give the right to take property by eminent domain, make provision for the payment of damages, and in the case of municipal and district supplies set up a board of water commissioners as the managing body of the works constructed and the property acquired. In cases where water may be diverted so as to result in damage to riparian owners or to those having water rights on the stream below the point of the diversion, damages when incurred may be paid as provided under Chapter 79 of the General Laws. In the case of the Great Ponds, however, there is no damage to the riparian owners. All of the enabling acts carry some provision against pollution of the water supply, and most acts provide that whoever wilfully or wantonly corrupts, pollutes, or diverts, any of the waters taken or held under the act shall forfeit and pay to the town, water company, or water district owning the supply, three times the amount of damages assessed therefor to be recovered by action of tort and upon conviction shall be punished by a fine of not more than $300 or by imprisonment for not more than one year.

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*Chief Engineer, Massachusetts Department of Public Health, Boston, Mass.

In addition, our public water supplies are protected by certain of the General Laws, of which the following are examples.

Chapter 114 of the General Laws, Section 35, forbids the use of land for burial purposes on a watershed of a public water supply without approval of the Department of Public Health.

Chapter 111 of the General Laws, Section 167, forbids the discharge of sewage, drainage, refuse, or polluting matter as either by itself or in connection with other matter will corrupt the water of any water supply within 20 miles above a filter gallery or the point where such supply is taken.

Chapter 111 of the General Laws, Section 170, provides for a fine of 1 000 dollars or imprisonment of one year for anyone who wilfully and maliciously defiles or corrupts any reservoir or other source of water supply.

Chapter 111 of the General Laws, Section 171, provides for a fine of 50 dollars for one who wilfully deposits excrement or foul or decaying matter in water used for domestic purposes, or upon the shore within 5 rods of the water, or for imprisonment for not more than one month.

Chapter 111 of the General Laws, Section 172, forbids bathing in any domestic water supply and provides for a fine of 10 dollars.

Chapter 111 of the General Laws, Section 173, gives the power of arrest without a warrant to any police officer, constable, any executive officer or agent of a water board, board of water commissioners, public institution, or water company, acting on the premises of such board, institution or company, within 5 rods of the water, of any person found in the act of bathing in a pond, stream, or reservoir, the water of which is used for domestic purposes.

Chapter 111 of the General Laws, Section 174, forbids the driving of any animal on the ice of any water supply except for the harvesting of ice or for hauling wood or lumber.

Section 160 of Chapter 111 of the General Laws authorizes the Department of Public Health to adopt rules and regulations for the purpose of preventing the pollution and securing the sanitary protection of sources of water supply. These rules and regulations provide for the disposal of sewage and other polluting matter, regulate the location of stables, hog yards, etc., and the establishing of rendering or other works, and forbid the construction of sewers or sewage disposal works or the establishing of cemeteries unless plans are approved by the Department. They further forbid bathing or wading in a water supply and fishing or boating without a permit.

The greatest protection is afforded by the adoption and enforcement of the rules and regulations under Section 160 of Chapter 111, and court decisions so far as we can ascertain have always sustained these rules and regulations. That they are unpopular from the standpoint of the fisherman and those who would swim in our water supplies is evidenced by the many pieces of legislation introduced into the Massachusetts Legislature during the past few years, the most vicious of which was introduced into the present session of the Legislature and reads as follows:

> Chapter ninety-one of the General Laws is hereby amended by adding at the end thereof the following new section: —
>
> *Section 60.* It shall be lawful to swim or boat, or except as otherwise provided in sections twenty-seven, thirty-seven, thirty-eight, thirty-nine, fifty-four and sixty of chapter one hundred and thirty-one, to fish in any lawful manner at any lawful time, in an of the fresh waters of this commonwealth, other than artificial reservoirs; provided, that in so doing no trespass is committeed and no pollution dangerous to public health in fact results. Any rule, regulation or order of any public board or officer, or any city or town ordinance, contrary to this section, shall be null and void.

Unlike the action of the New Jersey Assembly, the Massachusetts Legislature apparently does not believe in such practices, as the legislative committee reported this bill as "Leave to Withdraw".

It is the author's opinion that bathing, boating, fishing, and other forms of recreation on sources of water supply must inevitably result in pollution and should be prevented. Our water supplies were not provided for other than water supply purposes and should be used only for such purposes.

This opinion may appear inconsistent with that of a committee of the Public Health Engineering Section of the American Public Health Association rendered in their report to that association on October 20, 1927, which reads in part as follows:

> The pendulum must soon swing to a position more compatible with the various opposing uses of the watershed . . . considering all parties concerned in a clean watershed, and realizing that there is always reaction against restrictions in which the public does not have full credence . . . .
>
> It was not long ago that there was considerable resort to universal ownership of catchment areas. The doctrine of course is opposed to other uses of the watershed and its effect is to limit or totally deprive the commonwealth of pleasures or prosperity that may come from the widest harmonious use of the country's assets, of which the watersheds and streams required to supply water to our growing metropolitan areas represent a large item. The principle of watershed ownership has about reached the limit of its economic usefulness. It is tantamount to hoarding and opposed to greatest beneficial use.
>
> In our opinion, health officers and departments must not take an extravagant position. They must look at the problem in a broad light . . . . when a broad viewpoint permeates the watershed policy the courts and the public are apt to support the health officer in curbing unreasonable use more regularly than appears now to be the case . . . .
>
> The consumers themselves can easily make the supply safe and entirely potable. It is preposterous to deny mountain recreation to the multitudes that the consumers may be spared the inconvenience of water treatment . . . .
>
> Look on watersheds not as a single asset but as having multiple uses of value and try and harmonize all with the least inconvenience and restriction needed to preserve each one . . . . Swimming should be considered more for its uncleanly effects on the stream.

As a source of dangerous pollution it is of little importance. We are equally certain that water departments can easily, and therefore must, take the balance of the burden of protecting their own supplies by adequate water purification . . . ."

Such a report is most inconsistent with good watershed sanitation and when one considers the personnel constituting this committee and that the water of the average bathing pool not subjected to chlorination contains pollutional organisms in greater numbers than can be found in many of our streams laden with sewage, it is hard to conceive how any committee can arrive at such conclusions.

We have in Massachusetts probably the lowest typhoid fever death rate in the nation, and in spite of the threats of the fishermen and others I am conservative enough to believe that that group, which constitutes probably less than 3 per cent. of our population, will not be able to override the wishes of the other 97 per cent. who are proud of their water supplies and insist on keeping them safe and fit to use. With more than 70 per cent. of our water surface of lakes and ponds not used as water supplies, such bodies of water should be developed where feasible for recreation, but the use of the water supplies for such purposes should be discouraged.

In Massachusetts as in many other states we are facing a great deal of difficulty in protecting our supplies from pollution; super-highway construction has opened up previously inaccessible areas, and more and more our watershed areas are being cut by travel ways. Unless careful supervision is maintained, these conditions must result in innocent as well as wilful pollution. Similar hazards exist in connection with construction activities on the watershed. In this connection Massachusetts experienced a small epidemic during the past year and averted another only by chance discovery of the sources of pollution. Chlorination with or without filtration must ultimately be provided in many of our water supplies, but supervision of the watersheds should not in any case be dispensed with, as sole reliance on chlorination cannot be considered as a sufficient safeguard to the public health, and filtered sewage is a poor substitute for an unpolluted water supply.

A low typhoid fever death rate should not be an excuse to lower the bars of careful watershed sanitation. In the author's opinion the present practice of careful supervision of the watershed by water departments should be maintained. In this connection it is suggested that the water works superintendents secure a copy of the paper written by Mr. E. Sherman Chase, President of this Association, entitled "Numerical Rating of Public Water Supplies." If the various water works officials would attempt to score their water supply systems as outlined in this paper they would discover many weaknesses so far as protection from pollution is concerned which would otherwise not come to their attention. The purpose of this scoring system is not, as I understand it, to compare one water supply with another, but more especially to assist the water works officials in ascertaining the true condition of their own supply. The duty of water works officials is first to obtain a water supply recognized as free from pollution and then to maintain the supply in equally as good condition while under their management. To permit pollution of a water supply and rely on chemical treatment to make the water supply safe certainly cannot be construed as being in the best interests of the community served.

Discussion.

E. Sherman Chase.* I think Mr. Weston has summarized in an admirable way the sentiments of the members of the New England Water Works Association, and if there is any one of our members who has sentiments other than those expressed by Mr. Weston, I call on him to rise. I take the lack of response as unanimous approval of Mr. Weston's sentiments.

There is one thing in Mr. Weston's paper to which I think we, as water works men, should give attention: that is recognition of the desires of a considerable number of citizens, the fishermen. While we do not want them on our water supply reservoirs, I do think that we should lend our support to anything which will render the streams and the great ponds which are not used for public water supplies, more suitable for fishing and freer from pollution. To that end the members of this Association should lend their support to the stocking of waters that do not serve as municipal water supplies and to the cleaning up of bodies of water that may serve for recreational purposes. I think if we show a co-operative spirit we shall receive due consideration from the fishing fraternity in our own problems.

Mr. Weston has referred to the report of the committee of the Public Health Engineering Section of the American Public Health Association. Our water works superintendents are not public health engineers; yet over a long period of years we have fought consistently for maintaining the original purity of our water supplies. The effect of our long fight for such purity is reflected over many years in the low typhoid fever death rate of New England. I think it is fair to say, that year after year this section of the country has shown either the lowest typhoid fever death rate of any of the subdivisions of the United States, or next to the lowest. Isn't that right, Mr. Weston?

Mr. Weston. That is true.

Mr. Chase. I think that is due to the fact that we have insisted on innocence rather than repentance.

Percy R. Sanders.† We have a set of rules and regulations that are given to us by the New Hampshire State Board of Health. Concord's water supply is a Great Pond, and we have tried to stop boating and fishing only in so far as it is governed by these regulations.

We have purchased ninety-nine and some odd hundredths per cent. of the shore line. This has stopped much use of the Lake for recreation purposes.

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*Of Metcalf and Eddy, Boston, Mass.

†Superintendent, Concord, N. H.

During the last winter the C.W.A. had a project in mind to take one end of the lake, build a dam and open the waters to swimming. While the matter was not formally brought before our water board for action, it held a meeting and expressed disapproval of the project. The New Hampshire State Board of Health and the Concord Board of Health took the same action also.

PERCY A. SHAW.* Our practice is about the same as Concord's. We have tried to buy up the shore line. There are over 20 miles of it. The water works and the Parker Estate own about 90 per cent. of the shore line. We patrol the shores, keep a policeman on the watershed all the time, and chlorinate the water. We permit boating and fishing.

I would like to hear from some of the men in Massachusetts who use a permit system, how effective it is and how they like the way it works.

LEONARD C. ROBINSON.† We issue permits for people who have cottages on Lake Nagog and occupy the cottages. The system is not especially satisfactory, but so far we have got along.

HAROLD L. BRIGHAM.‡ We had a permit system for Lake Williams. It was not altogether satisfactory, and after a visit by one of the officers of the Massachusetts State Department of Health, the Water Board quickly revoked all permits.

Those who have read Mr. Devendorf's paper in this Journal on "Water Borne Disease in New York State," will remember that there is a responsibility on the part of the municipality and on the part of the water commissioners if they knowingly allow the safety of the water to be impaired. The advice of some of the most eminent water works officials and public health men in New England has convinced me that opening a reservoir for recreational purposes subjects the commissioners to a very grave personal responsibility and the city to a financial responsibility. If recreational activities of any sort are prohibited, reasonable means to keep people out are adopted, and fishing is prohibited, then if by chance an epidemic occurs I do not think the city would have a financial liability. It seems too bad that one must have an epidemic to convince some people that it is not right to close the ponds.

ARTHUR C. KING.§ We issue permits for boating and fishing. Of what value the permit system is, I do not know. The permit is really a registration of the boat rather than a license for the individuals using it, as the owner of the boat can have a dozen names on the permit, and any one of the dozen people can use the boat. The boat is numbered, so that if we see a boat or the people from any boat in a restricted area, or acting as we feel they should not, we have a means of tracing the ownership of the boat and presumably the identity of the people in it.

PRESIDENT CHASE. Are you fully happy with that situation, Mr. King?

MR. KING. I do not think that I would want to put it as strong as that. I do not feel that we have had any serious difficulties with it.

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*Superintendent, Manchester, N. H.

†Superintendent, Concord, Mass.

‡Superintendent, Marlborough, Mass.

§Superintendent, Taunton, Mass.

Francis H. Kingsbury.[*] Would it not be well for superintendents or water commissions to require an examination of persons to whom they give permits, to see whether or not they are typhoid carriers? On C.C.C. work, on some of the watersheds, it has been found that out of possibly a hundred men there were two or three typhoid carriers. Those men were eliminated from the gang working on catchment areas. I wonder if this question of requiring a negative test for being a typhoid carrier would not affect the issuing of permits.

Charles W. Sherman.[†] I do not know how pertinent this is to present day conditions, but I remember about the time when the first permits for boating and fishing were issued it became quite the fashion to go out canoeing with permits and then accidentally fall overboard.

President Chase. I suppose they were dressed in bathing suits when they went boating.

William F. Sullivan.[‡] The New Hampshire State Board of Health, through Mr. Howard and Mr. Duncan, is following up a system of close supervision and inspection of New Hampshire water supplies. Mr. Howard and his staff are on the alert and have advocated and obtained the passage of laws for the protection of water supplies which are comparable, in many instances, with the laws of Massachusetts. This Board is doing much to eliminate unsanitary conditions which are a menace to the water supplies of New Hampshire.

The late Charles Walker, who for many years, in the pioneering days of water works, was superintendent of the Manchester Works, was a vigorous and able superintendent of the old school, mixing his daily work with kindness and bluntness. He was much respected by the public and honored by the members of the New England Water Works Association and loved by his subordinates. He early sensed the dangers of accidental or careless pollution of surface water supplies. The Massabesic water shed was large and when this area was threatened by contamination and in turn the health of the inhabitants of Manchester was at stake his militant spirit was aroused.

In Mr. Walker's time the laws and the control of water supplies were more lax than they are today. He thought it was his duty to startle and awaken the public mind of New Hampshire and the people of his city to the conditions.

Massabesic Lake, a large and beautiful sheet of water capable of supplying the important and growing City of Manchester with a permanent supply was threatened. To him this was sufficient reason to act and to strike quickly. Unfortunately for a water supply it was near the city, and encroachments were made upon its shores and on the islands before the real danger was realized.

Camps, recreational and public resorts in numbers preempted special locations in a way that if continued would eventually mean an unsafe supply. The water works officials were alive to the situation and were doing everything reasonable to acquire possession of certain lands around the lake and on the water shed. Either there was not sufficient authority or there was need for more laws or Mr. Walker wanted no further delay in cleansing what to him and others were sore spots. He declared war and selected some of the most undesirable places and destroyed them with fire and axe. A hue and cry went up, he subjected himself to the laws of the state, but the grand old man's conscience was clear for he believed it was his obligation to purge the water supply of objectionable features and thus impress upon the minds of others that water supplies should be protected.

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[*] Massachusetts Department of Public Health, Boston, Mass.

[†] Of Metcalf and Eddy, Boston, Mass.

[‡] President, Pennichuck Water Works, Nashua, N. H.

I hope the necessarily drastic lesson of the old times will not be forgotten. Mr. Walker was willing to sacrifice himself at a time when there appeared to him no other alternative to safeguard the health of his community.

At Nashua, a fair supervision has been kept over our water supply. For many years land has been acquired around the ponds of the Pennichuck Water Works. We have tried to prevent boating, fishing, swimming and camping. People who assumed they had rights on our ponds used to place boats on them. After warnings and failure by the owners to take notice and remove them we smashed the boats. We feel more secure now in protecting the water supply because of present-day laws and the coöperation of the State Board of Health.

LEONARD W. TRAGER.* The laws and regulations for the protection of public water supplies in New Hampshire are essentially the same as those in Massachusetts. Under the present law the State Board of Health separately or jointly with the local health officer has the right to make and enforce regulations on water supplies. In so far as it is practical our regulations prohibit boating and bathing and recreational uses on all supplies except on lakes such as Winnipesaukee, Sunapee and Newfound, which are really large bodies of water used for small public water systems. On these large lakes we do not think it is necessary to have regulations prohibiting boating and bathing, although we do require people in boats and in swimming to keep a certain distance from the intake of a supply.

Then again we have a law, passed in the last legislature, which gives us an additional power to require improvements or to prohibit almost anything in order to secure the improvement or protection of a water supply. By these laws we can govern and control our water supply to the extent of prohibiting boating, bathing or whatever else is necessary. I believe that we have sufficient authority, and certainly we are obtaining very good coöperation on the part of the water-works officials.

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*Associate Sanitary Engineer, New Hampshire State Board of Health, Concord, N. H.

PIPE THAWING BY ELECTRICITY.

BY H. C. HAMILTON.*

[*Received May 1, 1934.*]

In introducing the subject of "Pipe Thawing By Electricity", it might be interesting to dwell for a few moments on the temperature conditions that existed in this section of New England during the past winter. Geologists tell us that the New England glacial period of many ages ago was caused by a constant temperature of approximately 9°F. less than our average temperature of today. I think the conditions of the past winter will aid us in believing that this figure is correct. From October 1, 1933, to March 31, 1934, this territory accumulated a deficiency of 599°F. The following table shows this condition by months:

Month	Temperature Deficiency—°F.	Average Temperature Deficiency per Day—°F.
October	32	1.0
November	110	3.7
December	177	5.7
January	−54	−1.7
February	319	11.4
March	15	0.5
6 Months	599	3.3

The average daily deficiency over the six months' period was only 3.3°F., but our experiences in house heating during these six months gives us an idea of the adverse effect of lowering the temperature only 3.3° F. Fuel dealers have advised me that the average household used twenty per cent. more fuel this past winter. If we assume an average indoor temperature of 70° F., the normal average temperature differential is 33.4°. This past winter it was 36.7°, an increase of approximately ten per cent. This increase of temperature differential of ten per cent. evidently caused us to burn twenty per cent. more fuel in order to keep our houses at 70° F.

The principal effect of these abnormally low temperatures is of interest to water works men because the deep penetration of frost into the ground caused many water pipes to become frozen. This situation became acute around the tenth of February, 1934. While the month of January was slightly above the average normal temperature, on January 29 a real cold wave started, and it continued through to February 11, with the exception of only one day. In these fourteen days a deficiency of 203° F. accumulated which amounted to 14½° F. per day. This condition is shown in the following table:

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*Standardizing and Testing Department, Edison Electric Illuminating Co., Boston, Mass.

Date	Minimum Temperature °F.	Deficiency °F.
January 29	−2	10
January 30	0	21
January 31	2	11
February 1	29	−6
February 2	8	9
February 3	3	16
February 4	8	13
February 5	9	13
February 6	3	18
February 7	1	16
February 8	−12	27
February 9	−18	36
February 10	−2	16
February 11	15	3
14 Days		203
Daily average		14.5

Small wonder, then, that with the frost already deep in the ground, this cold wave pushed it down to a point where service pipes froze by the hundreds.

The Water Department of the city of Boston called upon us for assistance to meet the crisis which was suddenly thrust upon them. As soon as possible three pipe-thawing outfits were mounted on trucks and put into service. These I shall briefly describe.

Outfit No. 1. This outfit (Fig. 1) was made up from a battery taken from a conventional electrical vehicle. The battery was arranged in blocks of eight cells each and was of 200 ampere-hour capacity. With the four blocks of eight cells each connected in parallel, 800 ampere-hours were available at 16 volts.

The battery was placed in a 1½-ton gasoline truck and provided with the necessary leads, etc. It was so arranged that it could be easily reconnected at night for charging at 64 volts.

Outfit No. 2. This outfit (Fig. 2) consisted of a booster transformer of 10 k.v.a. capacity with a primary winding of 110 or 220 volts and a secondary winding of 20 volts together with a 2½-kw. regulator. This equipment was supplied from the 115-volt service to the house where the water service was being thawed.

This, also, was mounted on a 1½-ton truck and provided with the necessary measuring instruments.

Outfit No. 3. This outfit (Fig. 3) consisted of a 36 k.v.a. 2300/230 or 115 volts. This regulator was used as a variable voltage transformer, being excited from one phase of an overhead or underground distribution circuit.

This outfit was mounted on a 2½-ton truck with proper fuse cutouts and measuring instruments.

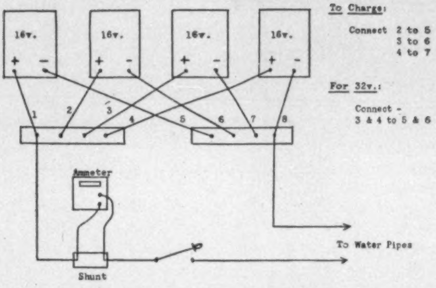
16v.
16v.
16v.
16v.
+ -
+ -
+ -
+ -
To Charge:
Connect 2 to 5
3 to 6
4 to 7
For 32v.:
Connect -
3 & 4 to 5 & 6
1
2
3
4
5
6
7
8
Ammeter
To Water Pipes
Shunt

FIG. 1.— SIXTEEN OR THIRTY-TWO VOLT BATTERY.

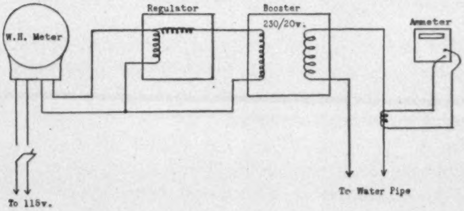
Regulator
Booster
230/20v.
W.H. Meter
Ammeter
To 115v.
To Water Pipe

FIG. 2.— BOOSTER TRANSFORMER AND REGULATOR.

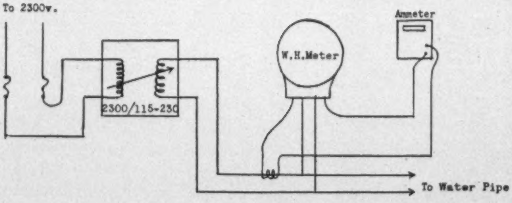
To 2300v.
2300/115-230
W.H.Meter
Ammeter
To Water Pipe

FIG. 3.— LARGE REGULATOR.

Outfit No. 4. I will make mention at this time of a fourth set (Fig. 4) which we used to thaw a transmission cable from a duct into which it had become so solidly frozen that thawing was necessary in order to remove it because of a fault. This set consisted of four 50 k.v.a. line transformers connected in series parallel. This connection enabled us to use 2300 volts as a source and 55 volts on the secondary side for thawing. It gave us an available current capacity of 1750 amperes and served the purpose very nicely.

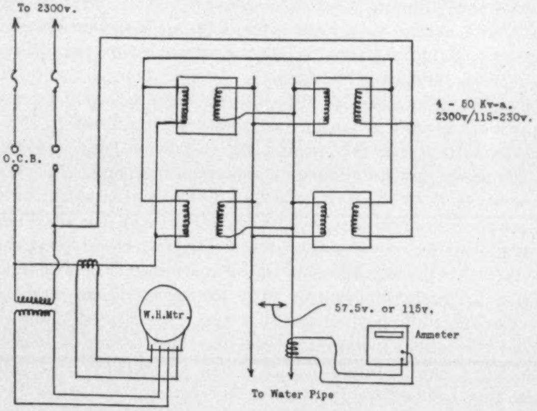

Fig. 4.— Line Transformers.

This outfit was used, as stated before, to free a section of 1500 volt, 4/0, lead-covered cable approximately 400 ft. in length. A loop was made of this cable with a companion cable in an adjacent duct line and current of approximately 300 amperes was used for one hour, the conductors being the lead sheaths of these two cables. The current was then increased to 550 amperes and held at that value for one and one-half hours. After application of 550 amperes for one-half hour the sheath temperature was 23° C. and remained approximately constant for the next hour when the circuit was opened. The cable was then successfully pulled from the duct.

I will now touch upon the advantages and the limitations of these outfits.

Outfit No. 1. The one drawback of this set was the necessity of recharging. It was used successfully, however, when thawing from eight to fifteen ¾-in. services in a 12- to 14-hour day without recharging. In one case, we thawed a section of 3-in. main with this battery with an average current of 800 amperes in twenty-two minutes. The big advantage of this set was that no outside source of energy was necessary.

Outfit No. 2. As this outfit was energized from the 115-volt house services, we were limited to a primary current of 50 amperes and a corresponding secondary current of 250 amperes. A great many ¾-in. services were thawed with this outfit, and it proved to be very flexible. This outfit has the advantage of smooth regulation of voltage, and, therefore, of current.

Outfit No. 3. This outfit was limited to positions where a distribution circuit could be used to supply the energy. It was, however, a very valuable set and was used principally on services that were so situated that a long electrical circuit was necessary and current up to 400 amperes was available at voltages up to 115. This outfit has the advantage of smooth regulation of voltage, and, therefore, of current.

Without question, the simplest and best electrical outfit for water-pipe thawing is a d.c. generator having a current capacity of 400 to 500 amperes at 115 volts, with proper field regulation, and driven by a gasoline motor. Some of the newer electric welding outfits are of this type.

A few words as to the routine to be followed in this work. It is necessary to disconnect the entrance pipe in the basement of the dwelling and all ground wires *must be* removed from the water pipe. One end of the circuit is then attached to the entrance pipe in the basement of the dwelling and the other end to a nearby hydrant or entrance valve. If the services to two adjacent dwellings are both frozen, the test loop can be made from one dwelling to the other. I want to stress the importance of disconnecting all ground wires, for it is possible, under certain conditions, especially where the service pipe has become broken due to freezing, to pass heavy currents over the metal coverings of house wiring, heating them at times to such an extent that fires have actually been started.

As to the current to be used in this work, the greater the current, the quicker thawing takes place. This can best be shown by the following table:

Average Amperes	Average Time In Minutes.
240	16.5
310	13.0
570	3.5

Since the heat varies as the square of the current, it would seem from this table that if a current of about 900 amperes was used the time would be very short. As a matter of record, in a few instances we did use currents of that magnitude. The time in those cases averaged a little less than one minute. The above records are for ¾-in. service pipes.

From our experience, it would seem that a current of approximately 400 amperes would do the work in a few minutes, and a minimum amount of danger to the water pipes would obtain. There is some danger in using currents in excess of 400 amperes in unduly heating the joints of the water pipes which probably have a higher resistance than the pipes themselves. Abnormal heat would be concentrated at the joint and, undoubtedly, would cause some damage. The Superintendent of the Water Department of the City of Boston told me that he fully expected some effects of this sort in years to come after electrical thawing.

In conclusion, it seems to me that a word regarding the cost of doing this work might be appropriate. In our work with the City of Boston Water Department we thawed electrically 165 service pipes. We also made 109 calls where pipes were supposed to have been frozen, and where because of existing conditions we were unable to complete our work. In a few cases the owner had called in a plumber and found that the pipes were frozen inside the house; in a few cases the inhabitants were not at home. In the majority of cases, however, connections were made and thawing was attempted but could not be accomplished due to broken service pipes. The average total cost for thawing each service was approximately ten dollars.

COLD WEATHER TROUBLES.

SYMPOSIUM OF MARCH 21, 1934.

P. R. SANDERS.*

The winter of 1933–1934 was the most severe in our experience. About one hundred services in Concord were frozen starting on February 7 and making it necessary to work nights and Sundays to keep services in operation.

The methods used to thaw out services were what water works generally use, namely, electricity or the use of hot water applied through small block-tin pipe.

We employed the Electric Company to thaw out forty services with electric current at an expense of $15 per service. This method worked to perfection except in the case of services that were connected to mains laid with Leadite joints. We expected some difficulty with thawing copper tubing but experienced none whatever.

We had two gangs using hot water for thawing services from cellars. For this purpose water was heated at the shop by a gas heater and fifteen or twenty gallons of hot water were taken in five-gallon cans to the job. We were able to thaw out services pretty fast in this way.

Services which had elbows or which were connected to Leadite-jointed mains had to be dug up. For this we used a compressor and found it of great use in driving down through the frozen ground. In several cases we found six feet of frost and in one 8-in. main, there were two inches of ice inside the pipe. We tested all hydrants by opening them and letting the water run. We found several hydrants frozen below the valve but were able to thaw them by using either hot water or steam from a boiler.

One 6-in. main was thawed by electricity.

The job that gave us the most trouble and work was the freezing of our 100 000-gallon elevated tank which is a reserve supply for East Concord and is on the same pumping service as our 2 000 000-gallon reservoir in the city. About three miles of 8-in. pipe supplies this district and the tank is located at the end of the line. The pipe crosses the Merrimack River, being packed in coarse granulated ground cork in a 2½-ft. box. We had no trouble whatsoever with this pipe on the bridge. Early Sunday morning, February 18, we had a leak in East Concord necessitating shutting off part of the village. We expected that the rest of the village would be supplied from the tank. Much to our surprise none of the takers in this section could get water. Upon investigation, we found that no water was coming out of the tank. This tank has a 5-ft. riser 132 ft. high and is 28¾ ft. in diameter at the top and 23 ft. high. We tapped into the manhole at the base of the tank and inserted a ¾-in. corporation cock. Exploring the tank through this corporation with a ¼-in. pipe, we found the tank frozen through from one side to the other.

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*Superintendent of Water Works, Concord, N. H.

Inspection of the tank showed ice 2½ ft. thick all around the sides at top and bottom. There were two layers of ice at the top, the upper layer 1½ ft. thick with a 6-in. air space above a second layer 1-ft. thick. We chopped out the upper layer and threw it out of the tank. Then we broke the second layer into small pieces. With a long ice chisel, we chopped through the bottom layer, going down into the stack a short way. We then got under the base and thawed out the 8-in. riser that went into the bottom of the stack. This permitted water to enter the stack.

After waiting two weeks and a half for a few warm days, an opening was finally made from top to bottom with the aid of the sun. So far we have found no leaks nor serious trouble with the tank from expansion of ice in the stack; a few of the seams may need caulking. Now that we know the dangers to which such a structure is exposed provision will be taken to insure a more positive rate of flow through the stack in future winters.

A curious feature about this tank is that while the flow line is at the same level as that of our 2 000 000-gallon reservoir, it will, when the pumps are running, overflow several hours before the reservoir is full. The diameter of the reservoir is 200 ft.; that of the tank is 28¾ ft. The tank is fed by three miles of 8-in. pipe and the reservoir by ½ mile of 20-in. pipe. The flow into the tank is controlled by a Ross relief valve.

George H. Finneran.*

The effects of the low temperatures in Boston during the winter of 1933–1934 were generally the same as in other cities of New England. We had our frozen service pipes, meters, hydrants, mains, etc. In comparison with the winter of 1917–1918, I think we fared better, especially so in connection with mains, hydrants, and service pipes. Only one main pipe was frozen and that was not of much consequence. There were not more than a half dozen badly frozen hydrants in which barrels or pots were split. Our hydrant-inspection force found many hydrants that needed attention, but fortunately they did not play a part in fire-department operations; we found them beforehand. We had about 600 frozen service pipes, as compared with 2 400 in 1917–1918. We were hit quite hard in the meter line, however, 3 600 having been damaged by frost, with more coming in daily. Most of these frozen meters were in cold cellars, which would seem to suggest that outside meters, while more expensive to install, will in the long run prove to be more economical.

When really cold weather started, our first complaints dealt with frozen pipes and meters in cellars where there was little or no heat. The pipes, in many cases, froze between the house stop cock and the cellar wall. This necessitated operation, on our part, of the curb cock. This work kept us busy throughout the winter, shutting off and letting on water to allow repairs to be made by the owner. The total number of jobs of this kind ran into four figures.

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*Superintendent of Water Service, Boston, Mass.

When the meter froze we removed it and set a "jumper" or connection piece in its place to maintain the supply until the Meter Branch could set a new meter.

When complaints of frozen pipes reached us early in the cold spell we advised the owners to get a plumber to thaw the pipes as they were, as a rule, frozen near, or in the wall, or a short ways out beyond. We found that plumbers were not equipped with apparatus for thawing pipes for any distance out and owners would again appeal to us. We then, upon receipt of a deposit of $15.00, would send our plumbers out equipped with small steamers and block tin tubes, and they would usually succeed in thawing the pipes, except in cases where a sharp bend in the pipe would prevent the continued insertion of the thawing tube.

Later, as the cold persisted and more pipes became frozen and the ice ran farther out into the street, we had to resort to the electrical method of thawing. We had an outfit of our own consisting of a low-voltage dynamo coupled to a gasoline motor mounted on a trailer, but while this was successful in all cases on which it was used, it could not keep up with the demand and we were obliged to call upon outside assistance. Before we finished, we had in service besides our own outfit, two electric-welding machines; one Edison set-up, one small booster transformer and one storage-battery outfit. The Edison set-up tapped 2 300-volt A.C. overhead wires and transformed the current into deliveries up to 400 amperes and 115 volts, which in turn were cut through a rheostat to suit conditions. The small booster transformer tapped 110 to 220-volt A.C. house services and was capable of delivering 250 amperes and 20 volts. The connection was made on the service switch, and the current was limited in the primary wires to 50 amperes to avoid overloading the electric service. The storage battery outfit could be connected for 16 or 32 volts and had a current capacity of 1 000 amperes. We also had a Darley outfit which we found to be somewhat limited in its application, although we used it with success under certain conditions.

A large section of Boston is served with direct current, and this somewhat handicapped us, as three of our units could not operate with that current. We were obliged to have the variety of apparatus described because of our inability to rent enough of one type. There was a great demand for all kinds of outfits from the cities and towns near Boston.

In making our "hook-up" we always disconnected the service pipe in the cellar as near the foundation wall as possible. One of the electric terminals was connected on the street side of this break in the pipe line to prevent the current from running back into the house. This was our invariable practice, and we had no fires or accidents of any kind. When the water came, its flow was controlled by the cellar stop cock.

We were put to much unnecessary expense by the failure of the occupant to run the water for some time after the service was thawed. We had to return to the same house again and again; in some cases, we thawed the same pipe three times. In other places it was necessary after thawing to keep the water running continually in a small stream, because the frost in the ground surrounding the pipe would freeze the water if left still for any length of time.

Many times we would go to houses on our list only to find them closed and the occupant who appealed for our assistance not at home. In other cases, after the water came, we found the house plumbing leaking and had to shut off the supply with the certainty of another freeze and another thawing job. Many times we arrived to find the service had been thawed by the owner who failed to inform us of the fact.

With the different types of thawing devices used, we had an opportunity to form an opinion as to the most satisfactory type for general use in Boston with its two kinds of current, and we think that the low-voltage dynamo coupled to a gasoline motor, is most suitable. A combination of about 20 to 25 volts and 400 to 500 amperes seems to be the best.

The electric-welding outfits that we hired proved very satisfactory. It would not be economical, however, for a water works to purchase one or more of these machines as they include an automobile chassis and the entire unit would lie idle during the greater part of the year, unless the water works went into the welding business. The welding concerns have an advantage in being able to use the machines in their business throughout the year. An independent mounting of the generating plant on a trailer or a platform that could easily be placed on a truck would seem to be the most economical and practical equipment. Whether in the event of frozen hydrant leads, or frozen mains, this type of outfit could furnish sufficient amperage, we had no opportunity of learning. In the past, when we were so unfortunate as to have frozen mains, we did not attempt to thaw them with electricity. We used steam which we considermore desirable in a big job.

Our experience with the booster transformer assembled and furnished by the Edison Company inclines us toward that instrument as a good one for a city or town where about all the buildings have A.C. current of 110 or 220 volts. This outfit, as stated, provided 250 amperes at 20 volts and was carried on a 1½-ton truck with a covered body. It did a lot of good work for us.

Difficulty seems to have been encountered by some of our members in passing current through a main with Leadite or Hydro-Tite joints. The Boston department made some experiments several years ago from which it learned that new Leadite or Hydro-Tite joints are non-conductors, but that after the joint is in the ground a few years it acquires a film on its face that will carry the current from pipe to pipe. Just how long it will take for this film to develop, I cannot say. The joints we experimented with had been underground six years. The film had the appearance of having been on the joint material for some time. Whether the formation of this film is dependent upon soil conditions, or whether it is produced by chemical changes in the joint compound itself, I cannot say, but it seems to be an easy matter to work out by any one sufficiently interested to know. Possibly the manufacturers may do a little research work and inform their customers as to how long and under what conditions a compound joint is converted from a non-conductor to a conductor of electricity.

In our experiments we learned that small pieces of cold lead inserted in the joint space and driven back hard so as to make good contact with bell and spigot made possible the flow of current from pipe to pipe. We used four of these plugs in each joint. They were about 1½ in. wide, 2 in. long and ½ in. or more thick. The long edge was tapered a little to facilitate forcing the plug back into the bell and up against the yarn. It is important to set the plug well back into the joint space. If it is flush with the face of the bell it will interfere with the flow of the liquid compound when the joint is poured. The less tar coating there is on the pipes where the lead plugs make contact, the better. It may be that before long a metallic packing will replace the braided yarn now used in making up compound joints and provide a path for the current to pass from pipe to pipe.

I have been interested in the old idea that frost descends farther into the ground during the spring thaw. I have observed that in the early spring when temperatures are running above freezing the frost recedes vertically in two directions in the ground. In other words, it thaws at the top and also at the bottom. The recession at the top seems to be faster than at the bottom. The walls of a trench will show this action plainly.

The expansion effect of winter freezing asserts itself more freely during the spring, through leakage. The solid ice will keep the cracked pipe, meter, or hydrant, watertight until the ice is thawed by rising temperatures; then comes the leakage and perhaps our first knowledge of the freeze. In Boston we have this as a yearly occurrence as late as the latter part of April. We rush to this and that place upon call and find a burst meter or service pipe in some building that was vacant during the winter. As warmer weather arrives, the frozen service or meter thaws and water escapes in all directions, calling for immediate attention. The same thing happens with pipes underground and crossing bridges. It is the outward sign of a long-standing inward condition, but it makes us think for a moment that the frost is still at work.

We had several main-pipe breaks with rather serious consequences which might be attributed to weather conditions. While factors were found in each case which regardless of cold weather would be considered dangerous, we think the precipitating factors were the low temperature of the water within the pipes and the heavy load of frozen earth on top of the pipes, which, with the concrete base of the pavement, transmitted the vibration of traffic down to the iron. This vibration would not travel so freely or hold its intensity so well through unfrozen earth. Furthermore, there must have been a stress or strain in the pipe caused by the formation of the frost. Wherever frost is forming there is movement, and this movement may have contributed the last straw to the already weakened pipe. When the pipes broke and the water escaped in large volume, the mass of frozen earth over the pipes would not allow the water to flow directly up and through the street pavement. Instead it deflected the flow to a horizontal direction and it shot through the foundation walls of adjacent buildings. Consequently the damage done was greater than if the water had flowed directly to the street surface and been carried away by catch basins.

Another adverse condition attached to these breaks and contributed by the winter weather was the thick ice that covered many of our valve boxes and caused delay in shutting off gates. Some of the boxes were not only covered with thick ice but water from the broken main covered the ice. These moments of high-pressure work, picking the ice off the valve boxes, working in swirling water, desperately anxious to get the gate wrench on the stem of the valve, made us realize fully that "it's a tough winter."

An extraordinary number of service-pipe leaks were caused by the frost heaving the curb boxes and pulling the curb cock and lead pipe with them. Ordinarily the frost moves only the top piece of the box which telescopes inside the bottom section, but last winter the frost went down around the bottom section and moved it up. Later the box will probably recede or be forced down by our men who look for projecting curb boxes. These movements up and down do not help a lead service-pipe in the vicinity of the curb cock.

Our experiences of the last winter should make us try to accomplish certain objectives that we have in our minds towards making conditions in our water-works systems such as to minimize the troubles that always accompany a winter of unusual severity.

Among them: We should relocate at greater depth those mains and services that we know have been reached by frost.

We should see that all new mains and service pipes are laid at a safe depth.

We should try to control the depth of service pipes laid in private property.

We should watch all changes in the grades of public streets and readjust our mains, hydrants and services to a safe depth.

We should try to abolish all dead ends, if practicable, and, if not, provide them with bleeders.

We should try all gates controlling the circulation of pipes over bridges in the late fall and see that they are open.

We should have test cocks in these pipes and means of quickening the circulation, if necessary.

We should lay our hydrant supply-pipes at a safe depth and have the pots or elbows well down in the ground. The wastes should work efficiently.

We should penalize cold cellars, the frequent origin of frozen service pipes; cellars with broken windows and open doors, and cellars with fireless heaters.

We should in some way require owners to have the supplies to vacant houses shut off and drained and the meters removed before winter arrives.

During a very severe winter we should let consumers understand that any water allowed to run for the purpose of preventing freezing would not be charged for, if contributing conditions were found upon investigation to be beyond their control. This would be a matter requiring good judgment and skillful handling as otherwise it might develop into a serious drop in the pressure. Education as to the small flow necessary and the method of insuring its continuity such as a nicked washer might be resorted to.

We should provide equipment for thawing, or make reservations for the hire of equipment so that when the severe cold cracks down on us it will not be necessary to go hunting and begging for apparatus and paying the owners high prices for it.

Under the head of equipment, I should try to have a steam generating outfit that was capable of forcing dry steam at high pressure into pipes. It will be of much value in large-sized pipes or where compound joints interfere with the use of electricity. In Boston this winter, the Gas Company had hundreds of services frozen and thawed them successfully with a hastily devised quick-generating steam outfit that resembled the steamer in the old Stanley Steamer automobile.

With these precautions taken our lot during an unusually cold winter may be a little easier.

WILLIAM F. SULLIVAN.*

During the past winter the cold weather in Southern New Hampshire was as record-breaking and severe as throughout the rest of New England. From November 1, 1933 to March 20, 1934, a period of 140 days, the thermometer registered temperatures below freezing on 132 days and dropped below 0° F. on 24 days. The coldest day, 24° F. below zero, was on December 30, 1933.

As the winter progressed and January came we sensed and observed from excavations that the frost was daily penetrating deeper into the ground and getting perilously near water pipes. A depth of five and six feet of frost penetration was found in a number of places. If a warning was necessary that difficulties were ahead for water works operators this observation was sufficient. It was clearly evident that flow in pipe lines, laid at shallow depths and especially in services which did not have a fairly rapid draft, was subject to interruption. Knowing that slow circulation inherently existed in the terminals, in dead-ends and in the outlying districts, and to avoid inevitable "freeze ups" we began early to increase circulation by bleeding lines apt to freeze. Nine hydrants were blown off daily. After thawing out services which froze more than once we allowed enough water to run to keep them from freezing. In the outlying sections, where there were no sewer connections, we laid small pipes outside the buildings and wasted enough water to prevent a recurrence of freezing.

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*President, Pennichuck Water Works, Nashua, N. H.

The water we furnish the public comes from the ground and is stored in a pond, or reservoir, having a capacity of about 56 m.g. During the coldest weather, the temperature of the water from the flowing wells was 54° F. In the storage reservoir, with the surface covered with six inches of ice, the water temperature at the pump intake went down to 37° F. Water from the city taps averaged 35° F. and for the larger mains in the center of the city the water temperature averaged around 40° F. From this we could reason that by providing continuous circulation in the shallow and dead-end pipes we could prevent freezing. Notwithstanding our precautions we had 39 frozen services. No frozen mains were discovered during or after the winter.

Part of our trouble occurred in the, so-called, development sections, that is where land companies "lotted" areas and sold the lots with rash promises to prospects, salesmen selling land with the promise that public improvements would quickly follow, such as, water, gas, sewers, graded streets and electricity. Seldom are these promises redeemed. After a time the city and the utilities try to ameliorate the living conditions of innocent property-holders. Usually the water-works service to these areas is of a temporary character. A tap from the main line is furnished, and if the promoters are well-disposed they will aid their clients by laying small-diameter pipes in ungraded streets and short cuts through vacant lots. The dwellings, often poorly designed and built, are "Home Sweet Home" to the occupants. The water works must regard a service to these properties as essential as in the better section if it can be furnished at a reasonable cost. Some day these modest home owners may have better streets and better buildings. When that time comes a water works will be in a position to extend and install larger and deeper pipes. We lay our pipes now with a cover of 5½ or 6 ft.

During the extreme cold weather, we dry-tested all hydrants frequently, not caring to open the hydrants and take the chance that many of them would not drain through frozen ground. This left us in some doubt as to their reliability for service. We were fortunate in not having a single frozen hydrant called into use by the fire department. In the middle of March when temperature conditions warranted, we made a complete test of every hydrant, in other words, we opened every hydrant to find out if water flowed freely. Eleven hydrants were found frozen. Nine were just caught in the valves. Two were frozen in the connections. In thawing we used hot water through block tin tubing. Occasionally steam from an old-time fire-engine boiler and an electrical apparatus rigged up by the local lighting company were used. The latter was kept as a standby in case we had any frozen mains.

As we had no frozen mains, our troubles were comparatively few. We credit this experience to the bleeding which increased the circulation where the flow would otherwise be sluggish. Increased flow may also be attributed to the fact that only a little over 50 per cent. of our taps are metered. Unquestionably water takers took advantage of this and let the water run more freely than they would have if they had paid on meter rates.

As a winter pastime water-works employees, sometimes, engage in discussion of the subject: "When it thaws does the frost go down?" The belief that it does comes, in part, from experience with house pipes and mains. These pipes, previously frozen, are found to be broken when the ice in the pipes thaws. To try and settle this question to our own satisfaction we decided to try a few simple experiments. While our tests may not be conclusive, we found that the frost went down and stayed down during the winter. One reason for this is that we did not have a real thaw for over four months. The average temperature from November 1, 1933 to March 20, 1934 was over 8° F. colder than for the corresponding period of the previous winter. For observation purposes we selected a location where there had been frost trouble at a depth of four and one-half feet. It was an open unshaded highway with a hard-surface top. The frost penetrated first through 2 in. of bituminous and sand top, then through 7 in. of gravel fill; below that was an old oiled roadway surface 1 in. thick, then came 12 in. of loamy dirt and below came sand and gravel (see Fig. 1).

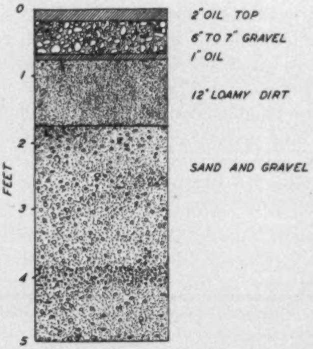

FIG. 1.—TYPICAL CROSS-SECTION OF ROADBED.

An excavation was made on the north side of the roadway and the frost layers observed and measured. On the following and each succeeding day a new hole was dug about three feet in advance and frost conditions noted. This was in March when the cold was expected to break. We found that while the weather remained cold and temperatures were below freezing

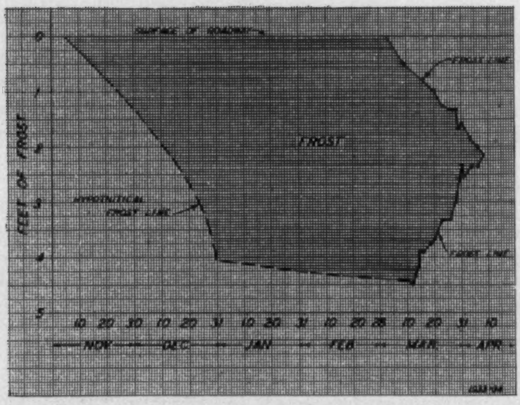

FIG. 2.—FROST LAYERS UNDER VARYING TEMPERATURE CONDITIONS.

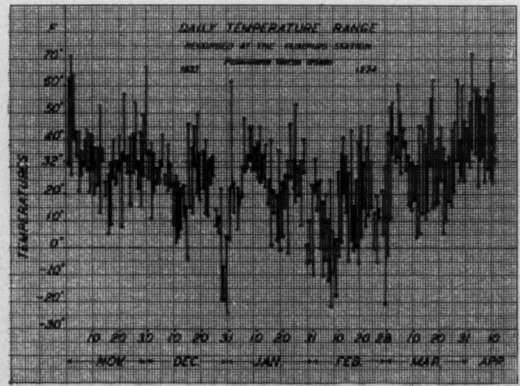

FIG. 3.—DAILY TEMPERATURE RANGE.
Recorded at the Pumping Station, Pennichuck Water Works.

sometime during the day the frost in the ground stayed stationary. When the less severe weather arrived and there was a longer range upward between minimum and maximum temperature we noted that the frost at the lower limits was lifting. When the thermometer was above freezing for a few hours, especially on days when the sun shone, the surface layers would thaw and quickly freeze again during the night. At the same time the frost at the lowest edge would thaw and not freeze again (see Fig. 2). The thawing action at deepest penetration was manifested in a honeycombing and disintegrating of the frost layers while the top layers alternately froze and thawed. The frost in the ground which was not affected by either the surface or ground heat remained solid about midway between top and bottom. This mid-section was the last stratum to thaw. During the tests a hole was dug about a foot lower than the frost line and temperature readings were taken which showed uniformly a temperature of 37° F.

A record of daily temperature ranges observed at the pumping station of the Pennichuck Water Works in Nashua is shown in Figure 3.

Francis H. Kingsbury.*

In addition to the troubles brought to water-works superintendents by the freezing of services and mains due to abnormal cold weather, there is also the feature of increased water consumption during such periods because of the water wasted by the householder and also apparently in industry to prevent freezing of fixtures and pipes leading to buildings from the public mains. Studies of water consumption in the past have shown that the winter of 1917–1918 continued cold from December to February, inclusive, and was one to which water-works engineers have pointed as an example of the increased use of water from public supplies because of cold weather.

It is interesting to compare the increased water consumption because of cold weather during the period December 1917 to February 1918, inclusive, with the similar increase during the period December 1933 to February 1934, inclusive. From the first of December 1917 to the last of February 1918 there was a deficiency of temperature below normal of 532° F., while from December 1, 1933 to the end of February 1934 there was a deficiency of temperature of 449° F. However, there was a difference between these two periods in that the temperature was below normal for three months in succession in the earlier period, while in the latter period the month of January 1934 had a mean temperature above normal, although February 1934 had the greatest deficiency in temperature of any of the months under consideration, three-fourths of the total deficiency for the three winter months having occurred in this month.

The records of water consumption in the Metropolitan Water District show that the winter of 1917–1918 had an increase in water consumption on account of the cold over that of the previous winter of 1916–1917 of from about 10 to 40 m.g. The water consumption for the winter of 1933–1934 showed a maximum monthly increase over the previous winter of about 20 m.g. per month. It is, therefore, apparent that the winter of 1917–1918 still remains the most striking example in recent years of the increase in water consumption due to cold weather. The following table shows these increases in water consumption on account of extreme cold weather in the Metropolitan Water District.

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*Massachusetts Department of Public Health, Boston, Mass.

INCREASE OF WATER CONSUMPTION IN METROPOLITAN WATER DISTRICT ON ACCOUNT OF EXTREME COLD.

Consumption is stated in million gallons daily.

	December	January	February
1917–1918	118.32	144.53	159.83
1916–1917	107.38	115.34	120.18
Increase due to cold.	10.94	29.19	39.65
1933–1934	127.03	131.55	145.15
1932–1933	126.37	126.38	124.16
Increase due to cold.	0.66	5.17	20.99

It is also interesting to inquire whether or not this increase in water consumption in the cold weather was due to wastage of water in residential communities. A study of the water consumption during the earlier cold period indicates that the greater portion of the increased water consumption took place in residential communities although so-called industrial communities showed an increase of from 10 to 30 per cent. per month over the corresponding months of the previous year. However, in the last cold winter the increase in water consumption over the winter of 1932–1933 was greater by about the same percentage than the previous year for both the residential and industrial communities. The possibility of increased industrial activity during the past winter over the winter of 1932–1933 may, however, upset any conclusions which might be made as to the responsibility of industrial communities for the increased use of water due to wastage.

It is quite possible, as the figures seem to indicate, that a portion of the increased use of water during the past winter has been due in part, at least, to increased industrial activity.

GENERAL DISCUSSION.

PERCY A. SHAW.* The causes of cold-weather troubles seem to have been principally three: an extremely cold winter, the plowing of streets and services laid at shallow depth.

Our last cold winter was in 1918. Then all vehicles in Manchester, N. H., were on runners,— even the hearse. Last year all the streets were plowed, and the cold penetrated the pavement and the frost went down. We have four or five records that I know of where we found the frost 5½ feet below the pavement.

Most of the services that got into trouble are what we call private services; that is, services put in by our customers. Many of them on the outskirts of town are from 100 to 300 ft. long. The owner thought it was too much trouble to dig down 5 or 6 ft., and some services are only 3 ft. deep. Those were frozen. In one day, nearly all in one forenoon, 44 frozen services were reported.

We have one electrical thawing machine using alternating current and rated for 300 amperes. When the 44 reports came in, we hired one more machine in town and two more from Boston. These were welding machines, rated for 300 amperes but built to carry 400 amperes continuously. With these we could thaw out a service sometimes in as little as five minutes, sometimes it took over an hour. When it took more than 30 minutes we decided that something was wrong, and since we had a lot of work ahead we would discontinue work and find out later what was the matter.

We had no difficulty in thawing out copper services, but it took longer. Where a galvanized pipe would be thawed in ten minutes, it would probably take thirty minutes for copper pipe.

We thawed two or three hydrant branches which had frozen. They consisted of 6-in. pipe with lead joints. We thawed these with two of the 300-ampere machines in parallel, carrying over 900 amperes. We thawed one in 14 minutes. With our own machine of 300-ampere capacity it took, as I remember, fifteen minutes to thaw one hydrant branch. But that is a whole lot easier than digging through 5 ft. of frost and trying to get the branch thawed out with steam.

The largest number of services thawed in any one day was 26. There were three days in which we thawed at least 26 services with four machines. Nearly all the 26 services were thawed with three machines. One of the machines we hired never thawed over four services in a day. The largest number of services thawed with one machine in one day was twelve.

A total of just over 300 frozen services was recorded. After we got four machines in use we quickly caught up with the demand. We had four machines for, I think, three days, then three, for a few days, and then took care of the remaining work with our own machine.

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*Superintendent, Manchester, N. H.

The answer to the problem of cold weather troubles, as I see it, is first, to lay pipe deeper. We found frost 5½ ft. deep in so many places that we shall lay our pipe hereafter at least 6 ft. to the bottom. We have been laying pipe 5 ft. to the top. The new practice will give us at least another 6 inches.

GEORGE E. HAWKINS.* We have not had any serious trouble in comparison with other places, but we have had our share of freeze-ups of water lines, service pipes. We had no thawing apparatus in the water department and we got the electric company to do the work. They had some trouble in thawing copper pipe, but after a satisfactory hookup was developed they succeeded in thawing the copper. We had no trouble with water mains except for two 6-in. dead ends. We provide a 5-ft. cover over our mains, but we have observed 6 ft. of frost in some places. Some mains must have been above the frost line, therefore, but we are fortunate in having a sufficient quantity of water to be able to direct users to let the water run. This has saved us a great deal of trouble. Of the two freeze-ups in 6-in. dead ends, one froze and burst, the other was thawed in about ten minutes by two electric machines in parallel with the transformers using about 600 amperes.

HARRY U. FULLER.† We had quite a number of frozen services in Portland compared with other winters. I have not counted them up, but they might amount to five hundred. We had no particular trouble in the streets, and if the houses and the cellars had been properly heated we would not have had a great deal of the trouble we did. Most of the troubles started with improperly heated cellars. A few 2-in. pipes and one 6-in. pipe were frozen for a short distance.

Recently I witnessed an occurrence that was due to the freezing. There was a fire, and the fire department hooked directly on to the hydrant, on the end of a 6-in. pipe, and reported that there was very little water. They sent for our superintendent, who was there in about ten minutes, and almost immediately after the superintendent got on the job the very small amount of water which they had been getting suddenly became very great. The superintendent informed me that he touched no gates, and there was no gate that could be touched because every gate in the whole works is wide open. It seems to me the most likely thing that happened was that the frost was down to the top of the pipe. There was probably considerable ice in the top of the pipe, with just a little bit in the bottom that was not frozen. For a little while they were getting a very small amount of water, but of course the comparatively warm water going through the pipe carried the ice away. In ten or fifteen minutes they had plenty of water. I don't know of any other way to account for it. I think probably it was a case of a frozen pipe.

We do not ordinarily open our hydrants in the winter time, so that we do not know for sure how many hydrant ends might have been frozen. In most of our system that matter is up to the fire department and is not the work of the water department. We have had quite a few meters which were frozen, but we adopted the policy that in a case where it seemed likely it would freeze again, after we thawed out a service, we notched a faucet washer and let the water run. That, taken with some other water that we ran through blow-offs, increased the flow of the water from a normal of about 13 m.g.d. up to about 18 m.g.d. We have plenty of water, and we think that is a comparatively easy and cheap way of getting away from these troubles.

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*Superintendent, Brattleboro, Vt. †Portland Water District, Portland, Me.

MR. HAWKINS. When our local electric company first attempted to thaw copper pipe they had no success whatsoever. They used a light cable and drew the current from the 2300-volt line. In thawing a 6-in. water main I had them use two transformers in parallel. Then I suggested to the superintendent to use the same equipment to thaw out copper pipe. We hooked on to the copper pipe for thirty minutes when I went into the basement and found they had just broken the union without fully disconnecting. I suggested that they break the coupling and disconnect it entirely, because the connections from the house line on to the pipe felt hot inside. As soon as this was done, the line was thawed in five minutes. It was about 36 ft. long. After that they had no trouble where they could reach 2 300-volt lines with the transformer. But 400 to 600 amperes from any equipment, either an electric welder or an outfit which is built for thawing water pipes, will thaw copper if the pipe is disconnected inside so that all current passes through the circuit.

FRANK J. GIFFORD.* Have you seen the pipe since it was thawed?

MR. HAWKINS. Yes. It is perfectly all right.

MR. GIFFORD. How about the fittings?

MR. HAWKINS. The fittings are in good condition. Thawing had no effect on them whatsoever.

MR. GIFFORD. Was that copper pipe the regular standard copper pipe, or copper tubing?

MR. HAWKINS. Heavy copper tubing.

MR. GIFFORD. Do you know what the voltage was?

MR. HAWKINS. It was 2 300 volts reduced to 110 volts by the transformer.

DAVID A. HEFFERNAN. †I would like to ask Mr. Fuller about thawing out copper pipe. Copper pipe fittings are put together with a blow torch; they are sweated. What effect does current have on those fittings?

MR. FULLER. We use electricity to a considerable extent in thawing pipes. It had been our experience, in past years, that to thaw iron or steel pipe might take six minutes. With our thawing machine, which has direct current similar to a welding machine, with a capacity of 500 amperes, and a voltage limited to 40 or 50, it takes about twice as long to thaw copper services. I had supposed up to this year that you could not thaw a copper service, because the copper would carry the electricity so well; but I learned that you can. It takes a little more amperage and about twice as long, but with the same machine used to thaw out iron services you can warm up copper services sufficiently to let the water through and carry away the ice. I do not know the effect of this method of thawing on soldered joints. I do not know that we had any soldered joints in the lines thawed.

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*Superintendent, Dedham, Mass. †Superintendent, Milton, Mass.

We have been using copper tubing in reconstructing our office buildings, and we put in dozens of sweated fittings. However, we have not had occasion to put the electricity through them.

We found out something this year that we had never experienced before. It has been our custom to pay little or no attention to grounded connections to the electrical fixtures in the house, and we had been in the habit of connecting one of the terminals from the thawing machine perhaps onto a faucet in the house, or perhaps just inside the cellar wall, and the other terminal to some point outside, such as a hydrant or a service in an adjoining house. We got away with this arrangement in previous years, and I do not know that it caused any trouble. But this year we encountered trouble. We found in a number of cases that the electricity was causing trouble back in the house. In some cases it fused the copper wires that supplied the electricity to the house. The wires would be burned off inside of the condulet in which they ran. In some cases the insulation around the electrical switches or fuse boxes was burned out. One story was to the effect that a house was filled with blue smoke. In another case, a house which was some distance away from the house on which we were working, which seemed to have no connection with it and was not inside of what we thought to be our electric circuit, lost its electric power due to the fact that the wires were burned off. We have on our board of trustees an electrical contractor, who has been looking into this matter pretty carefully. As a result of his investigation we have adopted a new policy. Before we put the electric thawing machine to work, we now disconnect the service entirely inside of the house, right inside the cellar wall, if possible, take out a piece of pipe, take out the meter, and remove all grounds which are on the street side of this broken place in the line. I think that this practice is going to cure all the troubles we have been having.

The reason that we were getting troubles in other houses was due to what is called the secondary circuit. Electricity is taken from the 2 300-volt circuit, and a certain number of houses are grouped together on a secondary circuit. There were opportunities for electricity to travel in ways that you would not expect if you were not an electrician, anywhere in this group of houses that are hooked together in this circuit. I have heard of other people having similar troubles, and probably we are not the only ones.

W. Guy Classon.* When we first used electric thawing we did not even take the trouble to take out the meter, or take off wires. We simply connected one terminal to a sill faucet on one house and the other to a sill faucet on the other. We thawed out a hundred or more services in this way.

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*Superintendent, Leominster, Mass.

There came a time, however, when we had to thaw the service to an old-fashioned house. The property had been remodeled but contained more or less old piping and old wiring. We connected the terminals to the sill faucet and to the curb box and had not been operating long before the owner came out and informed us that we were burning the pipes inside. We stopped the machine and went in. We were not melting the pipes but did melt a hanger to which two pipes running along the ceiling of the dining room were attached. The hanger had dropped off and burned a hole in the polished floor; the owner had kicked it on to a rug and it had burned a hole in that. We next hitched to the same curb box and to a faucet in the bath room. We had not been operating many minutes before the owner informed us of a smell of burning rubber. The source of this trouble was found to be an oil heater on which there was a piece of rope. Apparently everything was all right. We started operations again and were then informed that something was on fire. We rushed into the house and found the whole cellar on fire. There was no water to put it out, so we had to call the fire department, and the fire got up into the partitions before they could get it out. Upon investigation we found that some of the BX cable operating the oil heater ran over our water pipe. I had the city electrician look it over and two other electricians. To this day we do not know exactly what happened. Since this experience we have discontinued connecting to the sill faucets. We now go into the cellar, take out the meter, and hitch to the curb cock or the corporation cock or hydrant. We have had no further trouble since.

We were using between 250 and 400 amperes when the fire occurred. We have no trouble in thawing out copper services. Although we have not many copper services, we have thawed out several of them with no trouble. We did have trouble with one service. We had a repair sleeve with two rubber gaskets on this service, and the pipe of course was separated by an inch or more. We have had no trouble with split sleeves. We have been told that we can not thaw main pipes laid with Leadite or Hydro-Tite joints. We tried thawing a pipe that we had put in last fall and we could not do anything with it. But after the pipes have been in five or ten years we have no trouble whatever, if we use a very low amperage, say 150 to 200 amperes. But when we go up to 400 or 500 amperes for a few minutes we can not get any results.

Mr. Heffernan. Has anybody had experience in putting a high amperage through copper pipes with sweat joints?

Mr. Gifford. If you used 4 or 5 hundred amperes you would produce some effect on the joint; if you used less than 200 amperes you would not. Copper pipe can be thawed if the copper pipe has less carrying capacity than electrical wire attached to it.

Samuel A. Agnew.* We have had some experience with both cement lined and plain pipe, and we note no difference as far as freezing and thawing are concerned. We had the same experience as others in setting a house on fire. The Company owns no thawing machine but bought its current from the town. No protection was used in connecting the electric wires to the service pipe. Everything seemed to be going well until a pipe connection broke in the street and the house was set on fire. The wiring inside was all ruined in a flash — we rewired the house.

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*Superintendent, Hingham, Mass.

We also had some experience with the Snell couplings. There is a small space between the coupling's collar and the pipe. The current arced across this gap and burned a hole in the service pipe. We also had experience attempting to use a service rod as a conductor from the wire to the stop in the ground. In one case the current arced across from the rod to the service pipe, burning a hole in the service about the size of a lead pencil.

We had no success whatever thawing cast-iron pipe jointed with Hydro-Tite or Leadite. Low or high voltage or amperage was all alike. After a long try in one case the pipe was cut and thawed with hot water. In that case a small boiler was used, one which could be carried on a Ford truck. The boiler was filled full, a valve on the top of the boiler opened to permit expansion, the fire lighted and the water heated as much as possible. Town pressure from another source was connected at the bottom of the boiler and the hot water taken out at the top. This was a complete success. The greatest labor and expense were incurred in digging out the pipe, cutting it, repairing the cut piece and backfilling the hole. In this case about one hundred feet of ice were thawed, but the warm water striking the ice under a pressure of about fifty pounds required almost no time to cut its way through.

In another case where we attempted to thaw a 6-in. cast-iron line jointed with Hydro-Tite and where I did not care to dig up the street, I foolishly determined to thaw with electricity. Instead of thawing, the jointing melted out and all our labor of electric thawing in this case went for naught. The street had to be dug up to repair the leak caused by the melted joint.

We have no copper service pipe in use in the town and I can say nothing from experience, but the fact that the current burned all the insulation from the copper wiring the electric light company was using would indicate that, given enough current, a copper pipe would heat as well, at least enough to loosen the ice from inside the pipe. We thawed a 2-in. line with cold water — but it was not a very long section,— by simply holding a jet of cold water against the ice until it cut its way through. I believe our great trouble is still to come in the spring. Hydrant branches and cross-overs which undoubtedly have been frozen are only now beginning to let go. Recently I was in New Hampshire and I left word that if anything happened the crew would have to care for the job. I got home, saw the trucks were out, and concluded something had happened. By inquiry I found that a cross-over under the finest kind of macadam road in the Nantasket Reservation had blown up. The road surface was so tight and strong that a great section, about forty feet across, lifted up like a great blister before the water came through. I believe there are any number of hydrant branches and cross-overs which are now frozen and I am afraid the experience we had at Nantasket is to be repeated many times before we are through with our troubles.

HENRY P. GIDLEY.* At Fairhaven a 1¼-in. McWane cast-iron service ran to a boat office near the marsh. The service was about 60 ft. long and ran down a slope of about 6 ft. The service was frozen, and I thawed it by an electric machine which was rigged up by the electric light company. It drew 110 volts and 300 or 400 amperes. After we thawed this service, it delivered a little water but would not raise water to the second floor. There was a great noise, as if the flow was stopped. We went to the gooseneck and dug it up, about 60 feet from the house. We found the brass nipple plugged. As soon as it was cleaned out and connected we found a break in the service near the building. The water came up through the frozen ground. We found that where the lead was a little loose in the cast-iron hub an arc was formed and fused the lead into the cast iron.

We have had no trouble in thawing pipes with Hydro-Tite joints almost as quickly as galvanized pipe, using 300 to 400 amperes at 110 volts. The thawing machine was just a transformer from 2 300 volts, and was equipped with a salt barrel with the plates that could be lowered or raised.

We had a lot of trouble with breaks. Although frost did not penetrate more than 2½ ft. and our mains have 4 ft. of cover, we found that the frost heaved the ground so that in one case a 6-in. main was sheared off. That main had been in about forty years.

Several hydrants were heaved up by the frost. In one case the nipple from the main had raised the hydrant so that we had to lower it a foot.

MR. GIFFORD. How long had the joint compound mains been laid?

MR. GIDLEY. Six to ten years, I think.

MR. GIFFORD. I asked that question because we were told in 1918 that there was no reason why you could not thaw through a substitute for a lead joint because 23 per cent. of it was iron filings.

I suggest that we give the representatives of the joint compound companies the privilege of the floor.

GEORGE MCKAY, JR.† We are just getting out a bulletin on this subject. It reads as follows:

HINTS ON THAWING
WATER SERVICES AND WATER MAINS ELECTRICALLY.

From information we have been able to collect from those who have had experience in electric thawing of services and mains, where the mains are jointed with Leadite, we learn that electric thawing is possible through reasonable length of pipe unless there should be a decided break in the circuit, such as might be caused by a sleeve joint.

Six-inch and 8-in. mains have been thawed with connections as far as 200 ft. apart, or more, where just the ordinary bell and spigot joints are in the line. So far, it has been found impossible to complete a circuit and pass current where there are sleeves or like gaps in the line. In such a case it would be necessary to divide the length of the line into shorter sections until the location of such gap can be found. This could be done by excavating, or driving rods for contact points along the line of pipe.

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*Superintendent, Fairhaven, Mass. †The Leadite Company.

In the case of a service, if the first hook-up does not go through, a trial from a house line or fire hydrant on the other side of the service might succeed.

We understand that some mechanical joints, such as a patent sleeve, on a steel or iron service will break the current flow.

Also, we understand best results have been obtained at low voltages and with currents of 300 amperes to 500 amperes.

Apparatus that will give rheostatic controlled current up to 500 amperes, at from 10 volts to 32 volts, has been found to give best results. Many Welding Companies have such apparatus, although it may be necessary to connect two (2) machines in series to obtain the necessary amperage.

There are special thawing generators on the market which can be mounted on small trucks, trailers, etc. Such generators can be purchased from, among others, Engessor Electric Company, Watertown, N. Y., Schramm, Inc., Philadelphia, Penna. (the latter a welding machine).

One Water Company reports recent results as follows:

"We have successfully thawed out frozen service pipes that were tapped on cast iron mains with Leadite joints, also cement mains.

Size of Pipe.	Amperes Required.	Approx. Length of Pipe.	Approx. Time Required to Thaw.
¾ in.	250	300 ft.	3 to 10 minutes
1 in.	300	250 ft.	5 to 10 minutes
2 in.	400	150 ft.	15 to 30 minutes
3 in.	500	100 ft.	30 to 60 minutes
6 in.	500	225 ft.	2 hours

I might further add that we have had very good results in thawing out services with this particular generator and it has proven to be very efficient. It will thaw any ordinary house service connection in from two to five minutes."

Experience indicates the following:

1. The voltage should be kept low to prevent injuries to persons, curb stops, plumbing, etc.
2. Connections of the electric cables to the pipe be made as carefully as possible; scraping the surfaces to give best contact.
3. The distance between connections be as short as conveniently possible.
4. Connections to service lines be, if possible, outside of any light, telephone or other wires that may be grounded on the plumbing.
5. All connections should be tightly and securely made.
6. The main switch or fuses of lighting circuit be disconnected.
7. Water meter be removed from the line.
8. Connections to a curb stop be avoided if possible as it may be damaged or its lubrication destroyed.
9. Connections can be made to corporation cocks set in line; fire hydrant nozzles; valve stems or other good and safe connections.
10. Wrapping cable around a coated main is not the best connection if better connection is available.

We understand that considerable damage has been done in thawing with electrical apparatus where it was tried to force the current through the line too rapidly at a high voltage. One party expresses it as "using just enough voltage to 'ooze' the current through the line."

We also understand that in a frozen line there is always a film of water between the ice in the line and the wall of the pipe and that although water itself is a poor conductor this film of water will carry sufficient current for thawing purposes.

We are passing along the above information for what it may be worth and are endeavoring to obtain further information on this subject for the benefit of those who have cold weather conditions with which to contend.

MR. GIFFORD. I appreciate this publication on electric thawing but do not see that it deals with thawing through compounds.

MR. MCKAY. The publication deals with joint materials. At Trenton, N. J., Mr. Bugbee tells me, they thawed out 2 500 services without trouble. He said he used 250 to 300 amperes at about 10 volts, and did not see any good reason for using a higher voltage than is sufficient to get the current through the line.

MR. GIFFORD. I appreciate that, too, but I still have no explanation as to whether the manufacturers of substitutes for lead are going to do something so that we can thaw pipes under any and all conditions, whether we attempt to thaw in one year or ten years after laying the pipe. I, for one, would like to know how many years the pipe has got to be in before it will carry current. Also I wonder whether or not this successful thawing of pipes, where the joints are made with substitutes for lead, is not due entirely to the pipe being home against the hub, whether or not the troubles we have had, where we started to thaw pipes jointed with compounds, has not been due to a ragged edge at the end of the pipe that hit the bell of the next pipe and caused an arc that burned out this joint, whether or not there is not some way of producing a conducting compound that will permit thawing under any and all conditions.

MR. MCKAY. If there happens to be a break in the line you will not get the current through it, no matter what your jointing is. If you have enough voltage you might jump at least a fraction of an inch.

MR. GIFFORD. I am not going to argue about joint compounds particularly. I am interested in thawing water pipes. In the old days we were told to use a plug of lead of the carrying-capacity of a 4–0 wire. We used a plug of lead in the bottom of the pipe and pushed the pipe home so that we would be sure of a good joint. We got tired of using the lead and did not use it any more because we were told that we could thaw through the compound joints. We have many mains laid with sleeves in them that are joined with lead, and if you do not use too high an amperage you can thaw and get good results through lead joints. But I still do not know how to thaw through compound joints.

HERVEY A. HANSCOM.* We have had quite good success where lead wedges were used. We have also experimented with braided jute and copper around the braided jute. But I think much of the trouble is due to the method of laying the pipe. It should be pushed home.

MR. GIFFORD. How about the fellow who does not spend all his time getting the pipe home but still gets a good joint?

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*Hydraulic Development Corporation, Boston, Mass.

MR. HANSCOM. If you will lay the pipe deep enough you will be all right.

MR. GIFFORD. What is deep enough?

MR. HANSCOM. I think a 5-foot cover would take care of most conditions.

MR. GIFFORD. I have seen the frost 7½ ft. deep in this particularly cold weather. We always thought that 4½ ft. of cover was sufficient for this particular climate, but we are finding it is not so.

MR. HANSCOM. I think many people fool themselves on the depth to which pipe should be laid. I think we have a greater depth of frost near Boston than in New Hampshire or Maine. Around here we may have cold weather, followed by a snow storm; then a thaw that leaves the ground bare. In Maine, New Hampshire, and Vermont they may have a little frost in the ground and 6 or 8 in. of snow; that snow protects the ground. The coverage in many parts of Maine can be much less than it is in Massachusetts. I think a 5-ft. cover is sufficient.

A MEMBER. Mr. Hanscom forgets that they plow the roads in Maine.

EDMUND C. SANDERSON.* We have found a solution in Winchester. Where the main is laid with lead we send the electric machine; where it is laid with compound we send the hot water kettle. As a result we have no trouble at all.

HENRY E. HALPIN.† The experience of a hosiery mill in New Hampshire in attempting to thaw out some 12- and 18-in. cast-iron pipe with electricity may be of interest. This pipe line supplied a dye house, and the length frozen was about 750 ft. of 12-in. and 18-in. pipe. They had two welding machines hooked up in parallel, and the pipe was divided into three circuits. The first circuit was about 200 ft. long, part 18-in. and part 12-in. Nine hundred amperes were applied to the pipe for about twenty hours. They were successful in breaking through the ice plug. On the second circuit, containing 300 ft. of 12-in. pipe, 900 amperes were used for twenty hours. Considerable ice was loosened, but the section was not thawed out completely. The third section contained 250 ft. of 12-in. pipe, and 900 amperes were applied for thirty-two hours without success. I think that the pipe contained so much metal that the current was unable to heat it up and do the thawing. The mill was paying $4 an hour for each machine, and the bill ran up fast. Electric thawing was discontinued after seventy-two hours and the job completed with steam furnished by a road roller and piped into the ice plug at several points.

MR. GIFFORD. During the fall of 1917 there was very little rainfall. This last fall and winter we had a lot of rain, and I for one felt sure that we were going to have enough water in the ground so that its latent heat would take care of us. Knowing that the greater part of the trouble in 1917 was due to lack of rain — we had dry ground at that time — I thought that we would not have to worry so much. The temperature record was to me less important than the rainfall record.

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*Water Commissioner, Winchester, Mass.

†Factory Mutual Fire Insurance Cos., Boston, Mass.

CHARLES W. MOWRY.* Naturally the fire-service mains which are buried in factory yards are more likely to freeze than those in the city because there is no flow through the yard mains normally. When the cold snap continued, I sent out a circular letter to about five thousand plants north of the Mason and Dixon Line urging them to see if any of their mains were frozen. We had a remarkable response. All the letters received expressed appreciation of the fact that we had called attention to the matter. There were only about ten cases of frozen mains, and most of them were thawed by electricity. A few were thawed by drilling a hole in the top of the pipe, after digging a pit, and then taking a section of copper tubing and connecting it to the steam supply and pushing the copper tubing into the pipe. As the steam melted the ice the water flowed out of the hole and the copper tubing was pushed in farther until the pipe was clear. We were surprised to find, in this severe winter, how few of the underground fire mains that had no flow through them were frozen.

MR. SULLIVAN. Do you have any requirement in regard to cover?

MR. MOWRY. It is the same as that of the water works, but the pipes in factory yards would be covered with a blanket of snow in far more cases than pipes in plowed streets.

MR. HEFFERNAN. I would like to ask whether the water was charged for in the cities and towns where the services were bled. In 1917 and 1918, no charges were made in Milton.

MR. SHAW. At Manchester consumers were informed that there would be no extra charge for the water this winter.

MR. SULLIVAN. We took the meters out if they had a meter on.

MR. HEFFERNAN. What about charging for frozen meters? Would a charge be made for a frozen meter?

MR. SHAW. Yes.

MR. SULLIVAN. No, we are a private company.

MR. GIDLEY. We are a private company and we make a charge for frozen meters.

MR. HEFFERNAN. In Milton we were very fortunate. Only 89 services and 85 meters were frozen. The services we thawed out by pumping hot water into them through block-tin tubing, a quick and cheap method when practical. We did not have occasion at any time to use electricity. We had no trouble with frozen mains. Denatured alcohol is used in hydrants which hold ground water.

There is one thing I would like to mention, and that is in regard to advice for thawing frozen hydrants. Mr. Melley, my assistant, and one of the men at the workshop, bought a galvanized tank used for heating water in barber shops. It has a capacity of five gallons. It was equipped with the necessary fittings, such as gauge, relief valve and filling connection. It was set to blow off at 15 pounds. The cost of this equipment is only $15.00. We had occasion, where the Sewer Department had one or two sewers frozen, to use this apparatus. We had no frozen hydrants.

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*Factory Mutual Fire Insurance Cos., Boston, Mass.

ROGER W. ESTY.* Where the service was frozen on the owner's property we always made a charge. We also charge for any damage done to the meters. To find a freeze-up outside, in the street, we made a test at the curb to see whether there was any water at the waste hole. The first time a service was frozen outside we did the work of thawing at our own expense. We informed the owner, however, that he must keep the water running at all times and that if the service froze up again there would be a charge. We had to go back to perhaps six such services and had to thaw them out a second time; we made a charge.

A VOICE. Did you collect?

MR. ESTY. We have not collected all charges as yet, but we have collected most of them. We made arrangements with the electric light department for a flat charge to us for use of their equipment — a thawing device on a truck and a man — for $5 a service. We also had a little thawing apparatus of our own which we bought from Darley. That we connected to the house lighting circuit, on the inward side of the switch, and the electric light department made no charge for the current used. We invited the superintendent of the electric light company to see how this machine operated, and he said it used so little electricity that he would not make any charge. Incidentally we had to thaw his own house service. He wanted to know if we could thaw the pipes that ran through the partitions to his bath room. We made a connection in the cellar, and by using 200 amperes we freed the pipes very quickly.

ALBERT A. ROSS.† I can give you a brief resumé of what took place in Lexington. I had my share of freeze-ups. Although we were equipped with steam thawing outfits, the freeze-ups were coming in so fast that it was decided to purchase a small Darley electric outfit similar to the one used by Mr. Esty in Danvers. The cost was $165.

We had 137 freeze-ups. Of these 95 were thawed out with the Darley outfit, the balance being thawed out by the steam. All of our services have now been thawed out, but we have 1 000 ft. of 8-in. pipe with compound joints which we have not attempted to thaw out yet, as there is only one taker from this line. I would appreciate it if someone would advise me what procedure would be the best to take in thawing out a main with compound joints. The main in question was laid last year. We have found that it is possible to create an electric circuit through a main which has been in the ground five or more years, but were unable to do so with this main, which has been in the ground only one year.

I now have several men at work excavating various places along the line of the pipe mentioned before and it is proposed to make taps and attempt to thaw out the main with hot water.

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*Superintendent, Danvers, Mass.

†Superintendent, Lexington, Mass.

The electricity for thawing was furnished by a portable welding outfit.

Harold L. Brigham.* An 8-in. cast-iron sewer pipe, laid with compound joints, was frozen solid in Marlboro. We could not thaw it with electricity, and finally we got a road roller to do it. I took some heavy garden hose to carry the steam, and we were able to advance about 40 ft. an hour with it. About 700 ft. were frozen.

We had more than the usual number of breaks last year. One peculiar thing I noticed was that everyone of them was a radial crack. Our pipes are buried 5 ft., and we did not find any place where the frost ran down over 4 ft. In practically every case we found a stone — not of very great size, perhaps as large as your fist — bearing on the pipe, either on the top or on the bottom. Possibly that is the reason for the cracks. We thawed services with hot water, and of about 75 frozen services there were only 8 that we were not able to handle.

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*Superintendent, Marlboro, Mass.

THE CORROSION PROBLEM.

BY HAROLD C. CHANDLER.*

[*Read May 1, 1934.*]

Ten years ago, the chief problems of water supply treatment, other than water softening, were those of clarification, odor and taste elimination and disinfection. In order to be accepted as being entirely satisfactory for domestic use, water had to be clear, colorless, free from taste and odor and bacteriologically safe for drinking. The modern water purification plant has made it possible to produce water of such quality, and the consumer of to-day appreciates the fact that a considerable amount of money and effort are being expended to supply him with a pure and attractive product.

During the past few years, the attention of the water chemist has been occupied with problems of corrosion. Purification processes have brought out the importance of the corrosive action of water on distribution systems for the reason that chemical treatment has, in most cases, accelerated this natural tendency. Before any theories had been advanced to explain this increased corrosive action, Hazen suggested that in some way the chemical treatment of many public supplies stirred up the sleeping ingredients of the water and made them aggressive.

Existing theories state that corrosion depends upon the concentration of negative ions such as sulphate and chloride ions in the water adjacent to the metal surface and the amount of carbon dioxide and dissolved oxygen present. If it were not for the concentration of these negative ions near the metal surface the tendency would be for an equilibrium to be established where very little of the metal will remain in solution.

As most natural waters are corrosive, it has been the problem of the chemist to devise methods for protecting metal surfaces from being attacked by the agents of corrosion. Where a fresh iron surface is exposed, no treatment of water will prevent its solution. Cement-lining of pipes has done more to prevent corrosion than any other method yet devised, but coal-tar coatings merely delay corrosion until a protective coating of a more durable nature is supplied. Granted that cement-lined pipe is the solution of the problem, most of the pipes in service are not cement-lined and are in need of protection. Hence the importance of water treatment to provide this means of protection.

Lime treatment is the most effective and economical method of corrosion prevention. Baylis has pointed out that if the pH value of a water is maintained at the point of solubility equilibrium of calcium carbonate, or slightly above, an impervious coating of calcium carbonate will be formed in the distribution system, thereby reducing corrosion to a minimum. The only objection to the use of lime in preference to soda ash or caustic soda is that lime increases the hardness of the water, but not to such an extent as to be objectionable, except in cases where the water is hard to begin with. The estimated cost per capita due to lime treatment is small as compared with the losses due to leaks, damage to property, fire losses due to inadequate pressure and staining of bathroom fixtures and clothes being laundered where no protection against corrosion is afforded.

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*Chemist in Charge of Purification, Greenwich Water Company, Greenwich, Conn. A Subsidiary of Community Water Service, New York, N. Y.

When the alkalinity of the water is below 25 p.p.m. not as much protection can be expected to result from lime treatment as with water of higher alkalinity. In most cases, however, this method of treatment provides a coating in the mains sufficient to retard corrosion to such an extent as to warrant its use. For soft waters, a pH value of about 9.0 is required for the formation of a protective coating preventing the corrosion of iron pipes, and this concentration will also greatly retard the corrosion of galvanized iron and brass, inasmuch as zinc does not readily dissolve above pH 7.5.

Experiments with Greenwich water have shown that the maintenance of pH 8.5 to 9.0 in the filtered water at the plant reduces corrosion in the distribution system to the lowest possible amount, as indicated by physical and chemical tests of the water and lack of consumer complaints. Service lines have been inspected and found to be coated with calcium carbonate. In other words, in the case of all main lines, that is, lines in which the water is always more or less in circulation, it can be said that lime treatment has solved the corrosion problem.

In the case of dead-ends, however, the situation is far from satisfactory, particularly during the winter months. Tests show that corrosion occurs to a considerable extent and, furthermore, the mechanical scouring action of the water on the entire distribution system causes an accumulation of material in these lines, resulting in red water. Flushing only serves as temporary relief, and in some cases it has been necessary to bleed the lines continually. In cases where mechanical cleaning has been resorted to as a means of increasing pressure, the condition has been aggravated.

These facts are indicated in the following table of results of tests made at various points in the Greenwich distribution system during April of this year:

P.p.m. of	Plant Effluent.	4 Miles from Plant.	8 Miles from Plant.	Dead End.	Dead End.
Turbidity	1	1	1	7	15
Color	5	5	6	42	85
Alkalinity	22.0	24.0	21.0	20.5	19.5
CO_2	0	0	0	0	0
pH Value	8.6	9.1	8.7	9.1	9.0
Phenolphthalein Alkalinity	1.0	4.0	1.5	4.5	3.5
Iron	0.03	0.03	0.04	0.57	2.25
Dissolved Oxygen (% of saturation)	98	98	97	64	34

The conclusion to be drawn from these tests is that it is practically impossible to prevent corrosion in dead-ends by any known method of water supply treatment. Except where continuous flow is afforded, chemical treatment is not effective in forming a protective coating against corrosion and the solution of the dead-end problem probably lies in the use of cement-lined pipe, supplemented by lime treatment to prevent deterioration of the cement lining.

DISCUSSION.

ELWOOD L. BEAN.* I agree with Mr. Chandler that cement-lined pipes are a very certain way of stopping red water. I think, however, that it can be controlled quite satisfactorily by the use of lime even in a soft water, provided the treatment is carried to the point of saturation of the carbonates. In many New England waters that would represent a pH of about 9.6. Mr. Chandler's treatment at Greenwich is to a pH of 9.0, and he has stated that red water is still observed on dead-ends. There is some discolored water on dead-ends at Providence with a pH of 9.6 and where the saturation point of carbonates has been reached, but conditions are generally quite satisfactory.

In regard to action on galvanized piping, however, I cannot say that conditions are improved by increased treatment. It is true that zinc is not dissolved even at very low pH, provided it is pure zinc, but pin holes through the zinc coating on ordinary galvanized iron pipe, mill scale on the ends of the pipe, and various other impurities and imperfections in the coating will produce galvanic cells, which are extremely strong, much stronger than many of us have realized, stronger even than many of the stray electrical currents running from light wires, about which considerable has been written. These galvanic cells can destroy pipe rapidly.

GEORGE E. BOYD.* As regards adding lime to water for the prevention of corrosion rather than providing a resistant pipe lining, this would seem to be a matter of ordinary economics to determine whether an initial investment in a pipe lining, which would maintain full carrying capacity and not be subject to the drawbacks of chemical treatment, such as abrasive action, ineffectiveness in the dead ends, and additional hardness in the water, would be more economical than an annual expense for chemical treatment.

The principal objections to lime treatment are:

1. The hardening of the water, which brings about losses in boiler efficiency through scale.
2. Wastage in soap consumption.
3. In the textile industry, hardness in the water forms an insoluble curd with soap, which deposits in the goods, making irregular and uneven dyeing and affecting the quality of the finished product.

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*Water Purification Chemist, Providence, R. I.

*Wailes Dove-Hermiston Corporation, New York, N. Y.

4. When the pH value is raised much over 7, it prohibits the growth of yeast and affects the baking and brewing industry.

5. It causes deposits in the meters.

6. The addition of lime is not subject to exact control as to its even diffusion throughout the system and causes particular trouble on dead ends.

7. The lining on the pipe formed by lime to increase the hardness of soft waters and prevent tuberculation is generally soluble in that soft water so that a discontinuance of the treatment would mean that the soft water would again dissolve the thin film of lining and, therefore, the treatment must be continued, although the quantity can probably be cut down from that which was initially required.

As regards the loss in boiler efficiency, the Bureau of Mines, Department of the Interior, Technical Paper 218—on Boiler Water Treatment—shows the following table:

Character of Scale.	Thickness, Inches.	Composition.	Loss of Efficiency, Per Cent.
Hard.	1/50	Mostly carbonate	9
Soft.	1/32	Mostly carbonate	7
Hard.	1/32	Mostly carbonate	8
Soft.	1/25	Mostly carbonate	8
Hard.	1/25	Mostly sulphate	9
Hard.	1/20	Mostly sulphate	11
Soft.	1/16	Mostly sulphate	10
Soft.	1/16	Mostly carbonate	11
Soft.	1/16	Mostly carbonate	12
Hard.	1/16	Mostly carbonate	12
Soft.	1/11	Mostly carbonate	15
Hard.	1/9	Mostly sulphate	16

This expressed in dollars and cents means that with a deposit of 1/9-in. of scale, 16 cents of every dollar paid for coal is lost. This loss is enormous, but as it is somewhat intangible, it is not generally given due consideration.

Engineering News Record, June 30, 1932, page 916, shows the cost of soap waste due to hard water, as follows:

City.	Hardness. p.p.m.	Waste Per Day. Lb.	Waste Per Day. Cost.	Waste Per Year. Tons.	Waste Per Year. Cost.
Superior, Wis.	45	Base	Base	Base	Base
Bloomington, Ill.	70	280	$50.28	51	$18,332
Champaign-Urbana, Ill. . .	248	950	180.67	173	66,148
Chicago Heights, Ill.	555	1,060	224.43	193	81,918

Using Superior, Wis. as a base, Bloomington, Ill., with a hardness of 35 p.p.m. more than Superior, has an annual soap waste of $18 332 for domestic uses alone, exclusive of laundries or industrial plants. Since a softening plant was built, they show a soap saving of $308 per day for the entire city, amounting to 268 tons or $113 500 per year.

According to an article in *Water Works Engineering* for 1932, in the city of St. Paul, the hardness of the water caused a loss of soap alone of

$59.00 for each million gallons consumed. As an example, we understand the addition of lime to the Wanaque system increases the hardness about 4 p.p.m. For 70 m.g.d. the cost at an estimated cost of 20 cents per m.g. for each p.p.m. of hardness due to soap loss and boiler scale, equals about $20 000 per year. To this expense must be added the cost of the lime, probably another $20 000 annually. This capitalized represents a sum of well over half a million dollars, which would pay several times over for the lining of this system.

I think that these data indicate that it might be worth while for the engineer to make an economic study of the advantages of pipe linings as compared to lime treatment where a new transmission line or a new system is being considered.

ELECTRICAL GROUNDS ON WATER PIPES.

BY H. S. WARREN.*

[*Read May 1, 1934.*]

I greatly appreciate the honor of being invited to speak to the New England Water Works Association on the subject of electrical grounds on water pipes. There are four introductory explanations which I should like to make at the outset:

(1) Instead of speaking to you extemporaneously, as, in many respects, I should prefer to do, I have written out what I am going to say in order that there may be no chance of any question arising as to just what is said.

(2) It should be clearly understood that my remarks represent merely my own individual views and beliefs. I do not speak for any company or interest and do not profess that my ideas on the subject are shared by other individuals or organizations. While I happen to be chairman of the Article 9 Committee of the National Electrical Code, which deals with the subject of grounding, I have not consulted the other members of the committee with respect to this talk and I do not know what the majority opinion of the committee might be on some of the points to be mentioned.

(3) My remarks are concerned solely with the technical aspects of the subject. I am neither attacking nor defending any company's practices nor do I express any opinion with respect to the rights, duties, or responsibilities, of any of the parties concerned in these matters.

(4) Finally, as the subject is a wide one and involves many complicated reactions, it will be impossible to go much into detail on any phase of the subject. While it would be foolish for any one who has been in contact with this subject to claim entire freedom from prejudice, I shall be as open-minded and fair as possible.

Different Kinds of Grounds. Grounding is of two kinds — service grounding and protective grounding. Service grounds are employed in cases where the earth is used designedly as a part of an electrical circuit. Formerly it was a common telephone practice, particularly in rural districts, to construct a circuit of one overhead wire with earth return. In a few cases, principally in sparsely settled districts in the West, power distribution circuits have been similarly constructed. This type of electrical circuit, however, is seldom used in areas where there is a public system of water pipes.

The most important type of grounded electric circuit is that of the electric railway where the track rails are used as a return for the overhead trolley conductor. The rails being in contact with the earth, the current divides between rails and earth, including in the latter term any grounded metallic structures such as pipes and cables.

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*Director of Protection Development, Bell Telephone Laboratories, Inc.; Member of the Electrical Committee of the National Fire Protection Association, New York, N. Y.

In ordinary power distribution, circuits operating in most cases at about 2 300 volts to ground (in some cases 4 100 volts to ground) are used to convey power from the substation to transformers located near the consumers' premises. These are called primary distribution circuits. At the transformer, the voltage is reduced, usually to about 120 volts to ground, and circuits at this voltage, which are called secondary distribution circuits, are carried from the transformer to the consumers' premises. These secondary circuits are ordinarily of the three-wire type; that is, one wire, known as the neutral wire, is kept approximately at earth potential by being grounded. Between the neutral wire and each of the other two wires there is a voltage of approximately 120 volts as already stated. Due to the phase relations, the voltage from one outside wire to the other is twice this value or about 240 volts. Three-wire secondary circuits with neutral grounded have current in the earth only when there are two or more grounds on the circuit and then only to the extent that unbalanced loads between the two sides of the circuit create difference of potential between grounds.

Telegraph circuits formerly were almost universally of the grounded type with earth return but in recent years, with the development of carrier and other high-speed systems, there has been a tendency toward metallic circuit operation.

In telephone service there are important uses of grounds for various operating purposes. For example, on certain types of party lines the ringers used for calling the desired station are connected to ground. The same is true of coin collectors. In some cases ground return is used in the battery supply circuit for private branch exchanges. In telephone central offices the operating batteries, charging machines, and ringing machines, when in service, are grounded either at one terminal or at the mid-point. Aerial cables are sometimes grounded at their outer end for the purpose of reducing noise.

Protective Grounding. The most important use of electrical grounds, from the standpoint of our discussion today, is for protective purposes. It is important that electrical equipment in homes and places of business be adequately protected from the standpoint of the safety of the persons using or operating the equipment and from the standpoint of injury to the equipment itself or the premises occupied. This is true whether the equipment be for power or communication purposes, and the protective method or apparatus in such case always requires a path to ground for the foreign or dangerous current, whether from lightning or from some other electric system.

Where a building is protected by lightning rods, provisions for conducting the lightning surges to earth are a necessary and integral part of the installation.

TELEPHONE GROUNDS.

The protective grounding practices of telephone companies may be considered under four general headings: Central Offices, Subscribers' Stations, Private Branch Exchanges, and Outside Plant.

Central Offices. The central office ground electrode is in most cases the main water pipe entering the building. Where no water pipe is available, made grounds and other available metallic bodies, such as deep well casings and the like, are used. Distribution frames as well as the framework for switchboards and apparatus mountings are grounded. The central office protectors are grounded directly to the main distributing frame. Many of the exposed parts of apparatus and equipment are grounded by reason of being mounted on a grounded framework. Otherwise, it is not the general practice to ground exposed metal parts of telephone central office apparatus such as the shells of repeating coils mounted on wooden bases or key-frames inserted in wooden parts of switchboards. Cables entering the central office are bonded together and connected to the central office ground. In the case of underground cables, where this practice would introduce undesirable electrolysis conditions, insulating joints are placed in the cable sheaths inside the building close to the entrance point.

Subscribers' Stations. At subscribers' stations it is the practice, wherever a public water system is available, to use it as the grounding electrode for the protectors. If water pipes are not available, gas pipes may be used; otherwise, driven rods are resorted to. It has not been the general practice of the telephone company to connect to private water systems or to artificial electrodes used by another utility or used for radio or lightning protection.

Private Branch Exchanges. Grounding practices for private branch exchanges are generally similar to those for ordinary telephone stations except that the framework of the private branch exchange also may be grounded. Very large private branch exchanges are practically equivalent to small central offices, and the grounding practices for central offices are generally followed.

Outside Plant. Aerial cable sheaths are usually grounded by being bonded to underground cable sheaths which from their construction have low resistance to earth. Where aerial cables enter a central office directly, it is the practice to ground the sheath at the office, a water pipe, if available, being used as the grounding electrode. If no water pipe is available, an electrode separate from the grounding electrode of the protectors is employed for the outside cable sheath. Protectors, where required at the junction of open wire and cable, are connected directly between the conductors and the cable sheath instead of to an ordinary grounding electrode.

POWER SYSTEM GROUNDS.

The majority of high-voltage transmission lines in the U. S. A. are operated with their neutrals grounded either solidly or through resistance or impedance, but this practice hardly requires discussion here. The important case from the standpoint of safety is the grounding of the neutrals of power distribution secondary circuits.

These secondary circuits are brought into consumers' houses to supply power for lighting and other domestic purposes. They carry a voltage usually not exceeding 125 volts to ground, and this, under ordinary conditions, is not hazardous to persons in the house. An exception to this statement is in case a person is in a bath or either standing on a wet or other conducting floor, under which circumstances the resistance between his body and earth is so low that even 125 volts is highly dangerous.

If the neutral of the secondary circuit were not grounded, the wires in the house might, under any one of several possible accidental conditions, be elevated to a much higher voltage than normal and hence become a source of hazard. This might happen, for example, if the wires leading to the house became crossed with a high-voltage circuit or if the insulation of the transformer should break down, permitting the primary circuit voltage to become impressed on the secondary wires. If the secondary circuit leading to the house is exposed to lightning, a lightning discharge might momentarily raise the house wiring to a high voltage. For these reasons it is necessary, in order to make the installation safe, that the neutral of the distribution circuit and of the house wiring be solidly grounded, in such a manner as to make the path over the grounding conductor and grounding electrode into the body of conducting earth, of as low resistance as possible. For this purpose a continuous-metallic underground piping system for public water supply is by far the most effective grounding electrode there is. Hence, wherever such a piping system exists it is almost universally used for this purpose.

It is true that grounding the neutral point of a secondary distribution circuit and interior wiring system increases the chance that a person may be subjected to the normal voltage to ground of the wiring system. If the neutral of the interior wiring system were not grounded, a person, touching, for example, a water pipe with one hand and a portion of the live wiring with the other hand, would be subjected to only a small fraction of the circuit voltage, provided the circuit is in normal condition, whereas if the neutral is solidly grounded to the water pipe, the person making the previously-mentioned contacts would receive the full normal circuit voltage to ground. Hence, if there were no possibility that any high voltage would ever accidentally become impressed on the house wiring, the grounding of the neutral would be a detriment rather than a safety measure.

For the protection against lightning of substation equipment and of distribution transformers, it is customary to use lightning arresters, and these need to be grounded. Distribution transformers are usually mounted on poles, with an arrester on each primary wire near where it enters the transformer. The most effective grounding electrode for these arresters is, of course, a water pipe, but in many cases water pipes are not available at transformer locations and driven grounding electrodes have been extensively used for this purpose. In recent years it has been found that these arresters afford better protection to the transformer if their grounding conductors are interconnected with the neutral wire of the secondary circuit. Such interconnection is permissible under the 1933 edition of the code, provided the secondary neutral is grounded elsewhere to a continuous metallic underground water piping system in addition to the ground at the trasnformer.

In the early days of the National Electrical Code there was no mandatory grounding requirement. In fact, the code at first did not purport to contain any protective measures against life hazard but was concerned wholly with fire hazard. The insurance people, who were sponsoring the code at that time, took the position that they would be willing to insert a mandatory grounding requirement in the code, provided the electrical people would tell them what the requirement ought to be. Consequently, the American Institute of Electrical Engineers, through its code committee, took up a discussion of this matter. While all the members agreed that circuits of less than 150 volts to ground ought to be grounded, it was found that opinion was closely divided on the question of whether it would be advantageous or not to require the grounding of secondaries on circuits where the voltage to ground was more than 150 volts. It was finally decided to make the grounding mandatory on circuits not exceeding 150 volts to ground and permissible on circuits of higher voltage. The first National Electrical Code to contain this requirement was the edition of 1913.

The reason why a continuous metallic public supply water piping system makes the best ground is not because such pipes have water in them but is due to the fact that such a piping system has by far the largest contact surface with the conducting material of the earth. In fact, where such a piping system exists, it *is* the earth, electrically speaking, for all practical purposes. The hazard to be protected against arises from the fact that voltages may accidentally be set up between different metallic objects in the house and that persons may be subjected to these voltages. Water pipes appear at numerous points through the house and are interconnected or in contact with steam pipes, gas pipes, etc., so that they offer numerous chances for people to get in contact with them. If some other grounding electrode were employed instead of the water pipes, the voltages between electric wiring, apparatus, etc., and this extensive system of pipes might be much larger and, hence, the hazard much greater. The very presence of these piping systems in a house increases the importance of using them as grounding electrodes.

If by some extraordinary means, an equally low resistance grounding electrode were to be constructed in the same area independently, connecting to it would be substantially equivalent to connecting to the water system.

Of course, water piping systems having Leadite joints or other high resistance joints are less effective as electrodes than continuous metallic pipes, but still they usually make better grounding electrodes than anything else available.

In locations where water pipes are not available, protective grounding is usually accomplished by means of driven pipes or rods as grounding electrodes. Sometimes well casings, local piping systems, etc., are used either alone or in combination with driven electrodes. In general, gas pipes are not desirable as grounding electrodes because the methods of construction ordinarily employed cause the resistance to ground to be high.

Where a water pipe ground is available at a consumer's premises, a common grounding conductor and common grounding electrode are permissible both for grounding the circuit itself and for grounding the conduit, equipment, etc. A common grounding conductor and electrode are also permissible even if driven grounding electrodes are used, provided the distribution circuit which supplies this interior wiring installation is grounded elsewhere at two or more points. Under other conditions the present code requirement is that the conduit, equipment, etc., have their own grounding conductor and electrode independent of those of the circuit itself. Such independent grounding does not represent a desirable situation from the hazard standpoint.

Current on Pipes Due to Protective Grounding. The Code requires that protective grounding of power circuits be accomplished in such manner that there shall be no objectionable flow of current over the grounding conductor. The temporary currents set up under accidental conditions while the grounding is performing its intended protective function are not to be considered as objectionable. As already explained, the grounding connections are usually made at neutral points, that is, points which are normally at the same potential as the earth, so that grounding these points does not produce current. It is true, of course, that under the different conditions which occur in practice, the normal potential relations are sometimes disturbed, so that small currents will pass over the grounding conductors to and from the grounding electrodes. These currents may either come from the system which is grounded or they may result from voltages which have their origin elsewhere. It is pertinent, therefore, to consider whether current of this character can have any harmful effect on the water system where the water pipes are used as a grounding electrode.

The foregoing refers to cases when the circuit is directly connected to the grounding electrode. Most protective devices include spark-gaps, which, of course, prevent any current over the grounding conductor because the path to ground is normally open.

Kinds of Current. While some of you may not be very familiar with electrical matters, you all probably know that electric currents are of two kinds — direct and alternating. A direct current consists of a flow of electrons in one direction around a conducting loop. Alternating current consists of a flow of electrons around a loop, first in one direction and then in the reverse direction. In alternating-current circuits the time which elapses between reversals of direction of the current, determines what is called its frequency. The frequency most commonly employed in power circuits is 60 cycles per second, which means that the current reverses in direction 120 times each second. In telephone transmission the current is of a range of frequencies from 100 or less to 5 000 or 6 000. In radio broadcasting, with which people nowadays are very familiar, the frequencies range from 500 000 to 1 500 000 cycles per second.

In the practical case with which we are dealing, the currents are either direct currents such as from a battery or from an ordinary trolley railway, or 60-cycle, in some cases, 25-cycle, alternating currents. Extensive investigations have been made to determine the effect of different amounts of direct current on water pipes and other subsurface metallic structures, from the standpoint of injury due to electrolysis. Time does not permit going far into this subject, but I will say briefly that currents as large as hundreds of amperes have been carried by water mains for years, without producing any material effect on the water system. It is true that if a large amount of direct current is allowed for a long time to leave the surface of a water pipe directly to earth by means of electrolytic conduction, the pipe will be damaged by pitting or may even in time be destroyed, but effects of this kind do not occur so long as the current continues along the pipe until it is taken out through a metallic path.

In the early days of alternating-current railway electrification, the first large example of which was the installation of the New Haven Railroad, there was considerable apprehension lest current which escaped from the railway tracks and got upon underground pipes and cables, might cause damage by electrolysis to these structures. I recall that the telephone company arranged with the Westinghouse Company for a series of joint tests, which were conducted in two or three different locations in Western Pennsylvania, to secure data on the magnitude of the corrosive effects of 25-cycle alternating current such as is used in the New Haven electrification. We found in those tests, and the results we obtained have been confirmed by later investigations, that the amount of electrolytic corrosion by 25-cycle current was only about one per cent. of that caused by direct current under similar conditions. Other tests have shown that even this small amount of corrosion becomes less as the frequency of the current increases. It would not be expected, therefore, that any small currents, particularly alternating currents, which might pass to or along a water pipe as a result of protective grounding of electric circuits, could have any appreciable effect on the water system.

However, in some cases, water companies receiving complaints from consumers as to quality of water have suspected that current on the pipes from power, radio, or other electrical grounds might have caused impairment of the water. In one such case, investigations are now under way, and tests are being conducted seeking to determine whether these suspicions are well founded. Although I am in touch with these investigations, I do not feel that it would be proper to discuss them at this time or attempt to predict just what the results will be. I can, however, indicate, some of the reasons for my opinion that protective grounding, in accordance with the provisions of the National Electrical Code, does not affect the water in pipes which may be used as grounding electrodes. In reference to the above investigations, I will merely say that nothing has been brought to my attention which changes this opinion.

In connection with electrolysis investigations, it has been found that any injury to pipes by corrosion is limited to places where the current leaves the pipe directly to earth by electrolytic conduction. With alternating current the corrosive effect under similar conditions is, as stated above, less than one per cent. of that with direct current. Even if it be assumed that any considerable fraction of the current along a water pipe is conducted by the water in the pipe instead of the pipe itself, there is no reason to think that this would harm the water. Pure distilled water, i.e., water free from foreign matter, is practically a non-conductor of electricity. If the water contains sufficient other material to make it conducting, a very small part of the water might be decomposed into oxygen and hydrogen gas, but this should not injure the remainder of the water.

A simple computation will show how much current will get into the water in a pipe due to the presence of current on the pipe. Assume a ¾-in. standard welded steel pipe and water of 4 000 ohm-centimeter resistivity, a value which is within the range of commercial water supplies. The resistivity of iron and steel has quite a range of values as between different samples, but 11 microhm-centimeters represents a fair value for standard transformer steel. One ampere of direct current on the pipe would mean a voltage drop of 156 microvolts per foot of pipe. With water of the assumed resistivity, the resistance of a water column of 0.533-sq. in. cross-section and 1 ft. long is 35 500 ohms. The same voltage drop in the water as in the pipe would, therefore, correspond to a current of 4.4×10^{-9} ampere or less than one-half of 1/1 000 000 of one per cent. of the current in the pipe. In the case of alternating current, the proportion of current in the water would be even less.

It is interesting to compare the current in the water due to current along the pipe with the current set up in water by a galvanic couple. For this purpose our Protection Standards Engineer conducted an experiment with short pieces of brass and galvanized iron pipes, fastened together by insulating cement so that there was a separation of about 0.04 in. between the brass and the iron. By mounting these pipes vertically in glass vessels and capping the lower end, it was possible to add water and observe by means of a micro-ammeter the current between the dissimilar metals. New York City tap water was used, a small amount of potassium chloride being added to bring its resistivity down to 4 000 ohm-centimeters. The resulting galvanic current was found to be 220 micro-amperes. By comparing this with the results of the preceding computation, we find that the galvanic couple introduced 50 000 times as much current in the water as would one ampere of direct current on the pipe.

Another test was made with cells containing short pieces of pipe joined together by a coupling, the object being to see whether current longitudinally through the samples would affect the rate of corrosion. In some cells the two pieces of pipe were alike, both iron or both brass, and in other cells a brass pipe was coupled to an iron pipe. Each type of cell was arranged in three groups, one with no superposed current, one with an ampere of superposed alternating current, and one with an ampere of superposed direct current. The results obtained, after a 22-day run, are shown in the accompanying table:

Combination.				Corrosion Products, Milligrams.
Pipe.	Coupling.	Pipe.	Current.	
Iron	Iron	Iron	None	180
Iron	Iron	Iron	Alternating	160
Iron	Iron	Iron	Direct	153
Brass	Brass	Brass	None	6
Brass	Brass	Brass	Alternating	5
Brass	Brass	Brass	Direct	7
Iron	Brass	Brass	None	203
Iron	Brass	Brass	Alternating	158
Iron (−)	Brass	Brass (+)	Direct	151
Iron (+)	Brass	Brass (−)	Direct	164

It will be seen that the current had no appreciable effect.

Considerations such as these, of which a great many might be adduced, together with the fact that protective grounding introduces either no current at all, or at most very little current, even on the pipe itself, seem to constitute strong evidence that no harm to water supply can result, unless possibly under some very extraordinary condition. If, as a result of the examinations which are being, or may be, made, it should be found that, from the standpoint of water supply, any changes in the grounding provisions of the National Electrical Code are desirable, I have no doubt that any reasonable modifications necessary to meet these conditions could be worked out and incorporated in the code.

DISCUSSION.

CHARLES F. MEYERHERM.* Mr. Warren has pointed out that the grounding of electrical circuits on water pipes for protective purposes should not involve appreciable hazard or detriment to the water system. Most water works operators will probably agree with this point of view. Mr. Warren is also unquestionably correct in stating that the water works operator's objections to water pipe grounds arise from the fact that in practice ground connections often transfer stray electric current to or from the pipes either continuously or intermittently under normal operating conditions.

This interchange of stray electric current between ground connections and water pipes causes the water works operator who discovers it to wonder whether everything is as it should be or whether the current is having a deleterious effect on the pipe system generally or locally. Furthermore, if he investigates the situation he will probably find that such stray current interchange is far more prevalent than he anticipated, and that in some locations at least it will reach substantial magnitudes.

Sometimes this interchange is stray direct current from an electric railway system and often it is stray alternating current from the electrical distribution system. The stray direct current can of course be a source of serious electrolysis hazard to the water pipes and at times stray direct current interchange over the ground wires can entirely nullify the beneficial effect of insulating joints installed in water service pipes to prevent the access of stray railway current to these pipes and their consequent destruction by this current.

The point I wish to make is that when the question of the possible use of water pipes as protective grounds was first suggested, the water works interests were assured that such a use of the pipe system would not involve current interchange under normal conditions but only during the comparatively short and infrequent periods when the connections are performing their intended protective purpose. The National Electrical Code in recent editions at least definitely recognizes this principle and provides alternatives for use where water pipe grounds carry "objectionable current." The water works operator must, however, first find the current and object to it before he can begin to get rid of it. As a result he has serious doubts in his mind as to how much harm it may have already done and he still has the difficult task of finding some one to take the responsibility of saying that the alternative suggested by the Code will afford the required protection.

The problem is one which should be solved by coöperative effort on the part of the electric company, the water works operator and the city electrical inspector, or other authority, responsible for the enforcement of the code. The National Electrical Code goes about as far as can reasonably be expected in way of recognizing the difficulty and suggesting alternative methods, and it is a matter of applying the suggested remedial measures in the practical case. It is not good policy for a water department or company to order the summary removal of certain or all water pipe grounds even though it might be within its right in so doing, because this would merely put the whole burden of expense, annoyance and responsibility for substitute protective grounds on the property owner who knows the least about the problem and who would naturally react against the utilities and all others involved in the matter.

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*President and Engineer, Albert F. Ganz, Inc., New York, N. Y.

If the electric company as the source of the service for which the protective grounding is required would see to it that stray current interchange over the water pipe ground connections is minimized or prevented, practically all of the water works operator difficulties with these connections and objections to them would disappear. Protective ground connections to water pipes installed in accordance with the spirit and terms of the National Electrical Code would not present an electrolysis hazard to the water pipes nor would they be likely to have any other deleterious effect upon the pipes or upon the quality of the water.

M. W. Cowles.* The waterworks profession is very much indebted to Mr. Warren for his clear explanation of the paragraphs of the National Electrical Code which relate to the various types of grounds necessary to reduce the electrical hazards involved in our buildings. There are certain phases of the flow of current over ground wires onto water services and an apparent effect on the water itself, which I think are of decided interest to this Association.

In the past several years, complaints of an unsatisfactory tap water, involving peculiar metallic or astringent tastes, odors and discoloration or suspended matter, have been received at the Central Service Bureau of the Hackensack Water Company. On investigation, the complaint seemed to be confined to a particular building and the quality of the water delivered from a tap apparently varied from day to day, which facts did not indicate a general condition of the water in the mains. There was also occasional evidence of deterioration of brass pipe in certain parts of the water system of a building, and yet the pipe was relatively unaffected in other parts. No explanation from the usual investigational procedure seemed adequate. The usual corrective measures failed, and gradually observations pointed to the theory that electric currents might be causing the trouble.†

Preliminary field investigations with suitable electrical instruments indicated the presence of electric current, either alternating or direct, wherever these conditions were reported. Some 55 of the 75 complaints now on file in the Central Service Bureau, which apparently involve electric currents, have been further investigated by obtaining current readings with a specially designed D.C.—A.C. test set for a few minutes during the day hours. At 18 of these 55 locations, recording instruments have been connected and records obtained over periods of 24 hours or more.

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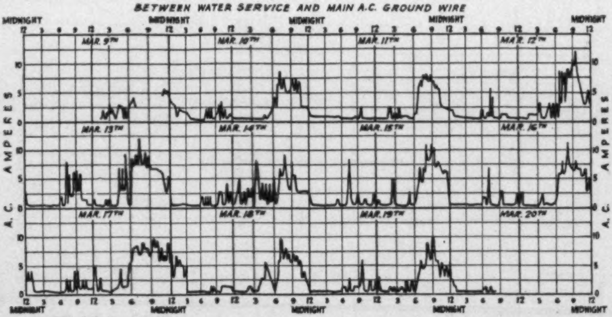
*Health Officer, Hackensack Water Company, New Milford, N. J.

†Jour. Am. Water Works Assn. Vol. 25, Oct. 1933.

The electrical readings showing the currents flowing between ground wires from electric distribution systems and house water services, are shown in the accompanying table for this class of complaints in certain of the towns supplied by the Hackensack Water Company. This table does not include the flow of alternating current or direct current (stray railway) on the water service itself. There is a considerable difference in the electrical picture as obtained from the two types of instruments. The charts produced by the recorder in several of these instruments, in condensed form, are shown in Figures 1 to 3, one being in a business district in Dumont and the other two in a residential section in Englewood. The magnitude of the alternating current between the neutral ground wire and water service is most surprising in view of the frequently heard statement that there is no current flow in the neutral as the transformer circuit is balanced. It is still more interesting when one considers that the path of the current along the water service is in parallel with the copper wire path and perhaps other paths and therefore the current entering the water service may be only a minor fraction of the total current flow, or a major portion, depending on the relative resistances of the several paths. The table also shows appreciable interchange of direct current between the water service and the overhead electric system. As Mr. Meyerherm has pointed out, such current interchange over ground wires is certainly "objectionable" whether intended by the code language or not. Practically a great many water services may carry appreciable amounts of current regardless of the code intent or meaning as explained so clearly by Mr. Warren.



NOTE - D.C. is negligible.

FIG. 1.—CONDENSED "TAPALOG" RECORD OF CURRENT FLOW, DUMONT, N. J., MARCH 1934.

Experimental removal of electric currents from water services under field conditions, where it has been done completely on a temporary basis,

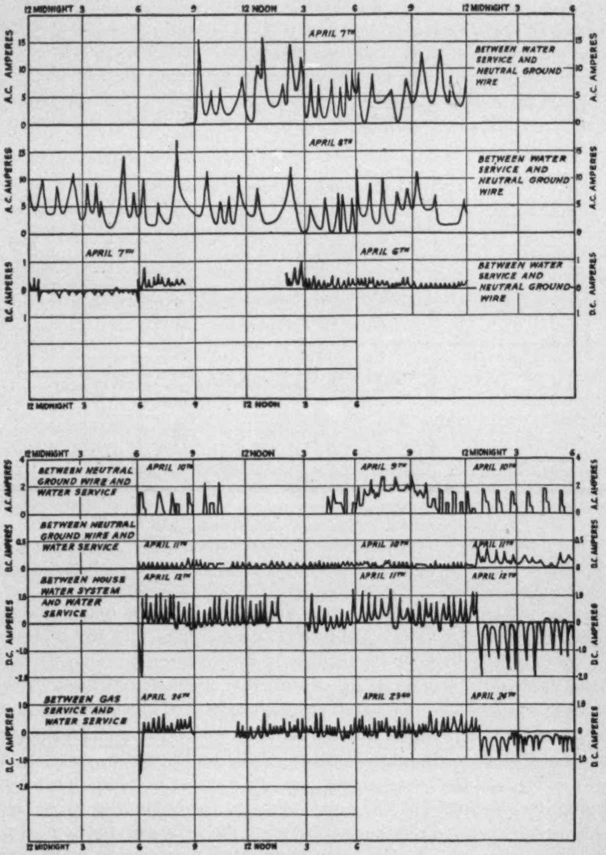


FIG. 2.—CONDENSED "TAPALOG" RECORD OF CURRENT FLOW, ENGLEWOOD, N. J., APRIL 1934.

has effected a considerable improvement in the character of the water delivered, indicated by the disappearance of odor, and a lessening of the discoloration or the amount of suspended material followed by a gradual decrease in the amount of taste in the water. In one or two cases of business buildings, improvement in the quality has not been as marked due to difficulty in removing currents from all portions of the water service lines. The length of time for recovery may be found to bear some relation to the amount of the current formerly flowing through the service. The field data indicate the presence of currents on water services suspected by reason of inferior quality of water, and the data thus far show an improvement of quality when the currents are removed.

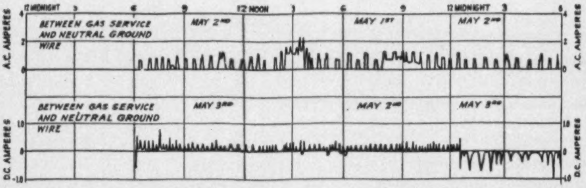


FIG. 3.—CONDENSED "TAPALOG" RECORD OF CURRENT FLOW, ENGLEWOOD, N. J., MAY 1934.

In the laboratory, experiments underway for nearly a year, using new water service pipes of galvanized iron, brass, copper and lead, with electrical and other conditions readily controllable, thus far indicate certain trends. Pipes carrying only about one ampere of current deliver a water containing odor and taste while the water from pipes not carrying current is relatively unaffected. Alternating current produced an effect not greatly different from direct current. An intermittent current apparently produces effects in general somewhat greater than does a constant current of some average magnitude. The removal of current is followed by a sharp reduction in the odor and a gradual reduction in the taste which parallels the observations made in the field. There seems to be no marked difference between the water delivered from the pipes of the several materials but further study of the analytical work may indicate otherwise. The concentration of metals in the water from the pipes without current show a fair agreement with the tastes produced. The concentration of metallic salts in water from the current-carrying pipes is somewhat greater but is not sufficient to account for the taste produced in the water. The theory as to the cause of the deterioration of the quality of the water, and any consequent effect on corrosion of the pipe material is still undetermined.

Similar observations have been made by the writer and others on other public water supplies treated and untreated from surface as well as underground sources, and the condition seems to be one of general occurrence for all water supplies to a greater or lesser extent and not peculiar to the filtered surface supply of the Hackensack Water Company.

The use of electrical devices, either motor-generator sets or transformers for thawing frozen services, during the extremely low temperature

MAGNITUDE OF CURRENT INTERCHANGE OBSERVED BETWEEN WATER SERVICE PIPES AND ELECTRIC GROUND WIRES WHERE BAD WATER COMPLAINTS WERE REPORTED AND THE TROUBLE WAS NOT GENERAL IN THE NEIGHBORHOOD.
Hackensack Water Company, Weehawken, N. J.
April 20, 1934.

Town.	Central Service Bureau No.	Date of Test.	Current.		Type of Test.
			Amps.	Kind.	
Cliffside Park	49277	Jan. 30, 1934	0.004	D.C.	Indicating Meter
			1.0	A.C.	Indicating Meter
	50135	Jan. 30, 1934	0.002	D.C.	Indicating Meter
			1.0	A.C.	Indicating Meter
		Apr. 4, 1934	1.8	A.C.	Recorder
	50230	Feb. 1, 1934	0.001	D.C.	Indicating Meter
			Trace	A.C.	Indicating Meter
Dumont	52468	Jan. 23, 1934	1.20	A.C.	Indicating Meter
		Mar. 3 to 20, 1934	14.	A.C.	Recorder
Englewood	35778	Mar. 19, 1934	0.009	D.C.	Indicating Meter
			0.120	A.C.	Indicating Meter
		Apr. 13, 1934	3.0	A.C.	Recorder
	43407	May 25, 1933	0.07	D.C.	Indicating Meter
			0.11	A.C.	Indicating Meter
		Apr. 3, 1934	1.0	A.C.	Recorder
	48703	Mar. 27, 1934	.....	D.C.	Indicating Meter
			Trace	A.C.	Indicating Meter
	49358	Feb. 1, 1934	0.015	D.C.	Indicating Meter
			0.52	A.C.	Indicating Meter
		Mar. 7, 1934	0.120	D.C.	Indicating Meter
			1.5	A.C.	Indicating Meter
		Apr. 7, 1934	17.0	A.C.	Recorder
	49455	Mar. 19, 1934	0.003	D.C.	Indicating Meter
			Trace	A.C.	Indicating Meter
	49847	Mar. 19, 1934	0.004	D.C.	Indicating Meter
			0.16	A.C.	Indicating Meter
	52832	Mar. 15, 1934	.....	D.C.	Indicating Meter
	56015	Mar. 15, 1934	.....	D.C.	Indicating Meter
			.....	A.C.	Indicating Meter
	57049	Apr. 13, 1934	0.005	D.C.	Indicating Meter
			1.9	A.C.	Indicating Meter
	57949	Mar. 19, 1934	0.002	D.C.	Indicating Meter
			0.26	A.C.	Indicating Meter
		Apr. 10, 1934	2.8	A.C.	Recorder

MAGNITUDE OF CURRENT INTERCHANGE OBSERVED BETWEEN WATER SERVICE PIPES AND ELECTRIC GROUND WIRES WHERE BAD WATER COMPLAINTS WERE REPORTED AND THE TROUBLE WAS NOT GENERAL IN THE NEIGHBORHOOD.—Continued.
Hackensack Water Company, Weehawken, N. J.
April 20, 1934.

Town.	Central Service Bureau No.	Date of Test.	Current.		Type of Test.
			Amps.	Kind.	
Hackensack	47134	Jan. 25, 1934	0.26	D.C.	Indicating Meter
	49098	Feb. 6, 1934	.....	D.C.	Indicating Meter
			.....	A.C.	Indicating Meter
		Mar. 24, 1934	.....	D.C.	Recorder
			✓ 2.7	A.C.	Recorder
	49792	Feb. 13, 1934	0.2	A.C.	Indicating Meter
		Mar. 8, 1934	Trace	D.C.	Indicating Meter
			0.20	A.C.	Indicating Meter
	51484	Jan. 25, 1934	0.10	D.C.	Indicating Meter
			0.74	A.C.	Indicating Meter
		Feb. 6, 1934	0.170	D.C.	Indicating Meter
			2.4	A.C.	Indicating Meter
		Feb. 9, 1934	0.004	D.C.	Indicating Meter
			.....	A.C.	Indicating Meter
Leonia	51037	Feb. 2, 1934	0.004	D.C.	Indicating Meter
			0.24	A.C.	Indicating Meter
Ridgefield Park	42386	May 25, 1933	0.002	D.C.	Indicating Meter
			1.58	A.C.	Indicating Meter
Rutherford	41786	May 19, 1933	0.003	D.C.	Indicating Meter
			0.91	A.C.	Indicating Meter
		Mar. 27, 28, 1934	3.9	A.C.	Recorder
	43959	Feb. 5, 1934	.....	D.C.	Indicating Meter
			1.50	A.C.	Indicating Meter
Tenafly	47124	Feb. 1, 1934	0.011	D.C.	Indicating Meter
			0.56	A.C.	Indicating Meter
	50823	Jan. 29, 1934	0.001	D.C.	Indicating Meter
			.....	A.C.	Indicating Meter
	51278	Jan. 29, 1934	0.002	D.C.	Indicating Meter
			.....	A.C.	Indicating Meter
	51548	Jan. 29, 1934	.....	D.C.	Indicating Meter
			1.30	A.C.	Indicating Meter
		Apr. 8, 1934	2.3	A.C.	Recorder
	52011	Jan. 29, 1934	0.010	D.C.	Indicating Meter
			0.19	A.C.	Indicating Meter
	55988	Mar. 26, 1934	0.100	D.C.	Indicating Meter
			2.5	A.C.	Indicating Meter
		Apr. 28, 1934	6.0	A.C.	Recorder
	56040	Feb. 28, 1934	0.30	D.C.	Indicating Meter
			0.40	A.C.	Indicating Meter
		Mar. 29, 1934	2.5	D.C.	Recorder
			1.25	A.C.	Recorder

of the past winter has produced some observation of decided interest in this connection. Our experience with the heavy currents used to thaw a service (300–400 amperes) indicates the production of a taste in the water noticeable over a period of several days but finally disappearing, and an increase in the amount of odor contained in the water. In many instances where the main is a part of the electrical thawing circuit, the very disagreeable odors of unusual intensity followed by complaints from other consumers in the immediate vicinity have resulted. In one case, actual electrolysis of the water occurred as evidenced by the reduction of chlorides. There is also ample evidence that the heavy thawing current may damage services and the joints in cast iron mains. It appears from contacts made by our organization that there is a surprising unanimity of opinion among water-works people that these large currents do have a detrimental effect on the water as well as the pipe structure.

Summary. The observations made in the field and laboratory investigation thus far tend to further confirm the theory advanced that stray alternating and direct currents on water service pipes do apparently have deleterious effect on the water delivered through such pipes. Many water services and water piping systems carry currents and the magnitude of the currents is very surprising.

Further laboratory research of highly involved chemical and electrochemical type seems to be necessary to explain the apparent action of the electric current by producing a deterioration in the quality of the tap water, and perhaps an abnormal stimulation causing rapid corrosion of the piping system.

It is necessary to secure the coöperation of all organizations concerned, including not only the water works industry and the electric power distribution industry but many others as well, not omitting the owners of buildings which are consumers of water and power, for only by such means can the problem of the control of stray currents in our modern communities be established.

Warren J. Scott.* I would like to ask Mr. Cowles who removed the currents from the individual services under observation.

Mr. Cowles. In most of the cases there were two types of current, alternating and direct flowing on the services. The direct currents were removed by inserting an insulating joint just inside of the cellar wall. In most cases that was satisfactory. The insulating joints were made of Bakelite or some substance of that character.

In removing the alternating currents, the coöperation of the electric power distribution company was necessary, and the company which operates in our territory very kindly consented to remove the ground wires at certain locations, on a preliminary test-basis. Such removal was permissible under the National Electrical Code provided the electrical distribution system was satisfactorily grounded elsewhere in the vicinity. That, however, represents a temporary condition for test purposes and does not represent a final solution for those particular premises.

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*Chief Engineer, Connecticut State Department of Health, Hartford, Conn.

R. M. PALMER. Mention was made by Mr. Cowles of the fact that some of the water was found to have an astringent taste. It is well known that an astringent taste has at times been traced to the presence of abnormal amounts of zinc in water. Was the water analyzed for its zinc content?

MR. COWLES. Analyses of the water from the special test pipes were made for four metals,—iron, copper, zinc, and lead. Sometimes in water from the pipes which did not carry current the relation between taste and zinc-content was fairly close, but not in water from pipes which carried current. Incidentally, zinc probably has more taste sometimes than some of the other metals. I cannot remember just at the moment the actual taste value that I determined for a zinc solution of known concentration. But in general the presence of zinc in water does not explain the taste where electric currents are involved.

MR. PALMER. It seems to me that we are creating a certain amount of mystery in connection with this question from a chemical angle. Certainly the decomposition of water into hydrogen and oxygen would not impart a disagreeable odor to the water. That is one point. The second point is this: Have these cases of taste and odor which have been traced supposedly to electrical current been carefully studied for the presence of algae?

MR. COWLES. There is no change in the amount of algae in the water. There were none to start with and there were none afterwards. There is no change in the bacteriological content of the water as far as we have been able to determine.

As to direct electrolysis, there has thus far been no evidence to indicate a chemical change in the water as regards alkalinity or hardness, sulphates, nitrates, chlorides, or any of the usual determinations used by water works people, but there is a possibility that the change, if any, may be beyond the limits of precision of analytical methods that we now have available.

In regard to the production of oxygen, electrolysis as such will probably produce hydrogen and oxygen, followed by numerous other secondary reactions, varying with the concentration of mineral salts present and probably many other factors. There has been some production of bubbles of a gas, very slight in amount, but no general increase in the amount of oxygen. Generally speaking, there has been a decrease in oxygen in the water from the pipes, greater where the pipes carried current than in those which did not. The oxygen decrease may be due to absorption by some material in the water or by the metal itself to form an oxide.

GEORGE F. MERRILL.* We used 300 or 400 amperes,—for thawing a 1-in. service connected to a 6-in. main. There was quite a good deal of complaint of bad-tasting water from a dead-end. However, the people who said the water was so bad got water from other houses on the dead end and said it was good. It seemed to me, therefore, that a good many of the complaints were imaginary. That was the only case in which we had a complaint. We used an electrical system of thawing in probably fifty different cases without similar complaint, but in all these cases there was good circulation in the main. That might account for the difference.

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*Ware, Mass.

There are a good many things about grounds on pipes which are rather a mystery to the average water works man. While we do not now have trolley current, we have about three or four different kinds of grounds: electric light grounds, telephone grounds, and radio grounds. I have found in one case, where we tried to thaw by electricity, that we had another kind of current which did not mix very well. We got bills for a couple of radio sets. That was undoubtedly due to a break in the line that we were trying to thaw, and the heavy current probably went up on the electric light line through some ground and back into two other houses through grounds.

Henry T. Gidley.* A while ago there was a leak in a curb box in the sidewalk and we sent a man to dig up the pipe. When he got near the pipe sparks jumped from the pipe to the shovel quite noticeably, so that the man thought it wise to disconnect the ground. He took a screw driver to accomplish this and melted the end of the screw driver in disconnecting the ground. On informing the electric light company of the trouble, they found that in making some changes on the corner, half way down the block they had connected a live wire to a ground. That would seem to be a very dangerous situation.

I understand that the reason the electric light people ground to the water pipe is that it renders them the greatest service. Did you ever hear of a lighting company allowing the water company, without permission, to attach wires so that they could tell when a standpipe or reservoir was full of water?

President Chase. It is a poor rule that won't work both ways.

Roger W. Esty.† We wanted to run a wire on three poles that were owned by an electric light company, and they wanted us to pay them $100 for the privilege and $6.00 a year as a rental charge.

I can not agree with Mr. Warren that the grounding of wires has no effect on the water. Last year I had a complaint from a drug store that when they drew water at the fountain it came through with a greenish or bluish hue. I looked the fixtures over and found that you could get clear water from every faucet in the building except at the fountain. I looked over the grounding and found the main ground wire attached in back of the shutoff; but there was another wire which grounded the outside of the BX Cable to the brass pipe which ran up to the faucet at the fountain. I disconnected that ground and since then they have had no trouble with the water.

We have had one other interesting experience. We were thawing out a ¾-in. galvanized pipe which went across a yard from an office building to a filling station, a distance of about 160 ft. We made a thawing connection between the buildings with our wires. In the two buildings there were altogether three ground wires. Before we disconnected I thought I would see what effect the ground wires would have on the thawing amperage. When I first made the connection I saw that we had 100 amperes. We disconnected one ground wire and it dropped to 90. In disconnecting the second one arcing occurred. Finally we got the wire off and disconnected, and the amperage dropped to 80. We then disconnected the third ground wire and it dropped to 75. I think that shows that it is essential, when thawing out pipes, to make sure that all ground wires are disconnected.

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*Fairhaven Water Co., Fairhaven, Mass.

†Superintendent, Danvers, Mass.

GEORGE E. BOYD.* With regard to the question of taste in water apparent after thawing frozen pipes with electricity, might not this taste be attributable to the fact that when water containing any hardness is frozen, the calcium and magnesium salts are concentrated in a central core. Such a core, upon melting gives a slimy appearance and perceptible taste. For this reason, in the manufacture of raw water ice, the cores are generally withdrawn and replaced with fresh water. If this is not done and a cake of raw water ice, containing the core, melts in an ice-box, objectionable slime is produced in the refrigerator. Any such taste or odor in a water main, after thawing, should rapidly disappear so it should be easy to determine whether such taste or odor is caused by the electric current or by the concentration of calcium and magnesium salts.

The matter of electric currents on pipe lines is a subject about which a great deal has yet to be learned and it might be well to consider whether or not the grounding of electric lines on a water pipe is the sole cause of these currents. It is well known that on some of the large natural gas and oil lines in the West sizeable electric currents are found many miles from any possible source of electric energy. Dr. Meighell of Stone & Webster once advanced the theory that such currents were static electricity induced by friction of the materials through the pipe and pointed out that these currents appeared to be greater close to the pumping stations. The matter of static electricity on pipes and hose is well recognized by the care with which the oil and gasoline companies take with their tank trucks and barges, by grounding them first to prevent explosions. Mr. Fletcher, Technical Advisor to the Marine Department of the Vacuum Oil Company, pointed out that in all cases of explosions, due to static electricity, they have found that the humidity has been below 60 per cent., and, as a matter of interest, pointed out that there have been several cases where explosions have taken place in hospital rooms caused by sparks generated through the friction of the ether in the hose supplying the patient.

There have been numerous studies on electrolytic corrosion, one of the most recent being, "Methods of the Location of Pipe Line Corrosion by Surface Electrical Measurements," by C. and M. Schlumberger and E. G. Leonardon, Paris, France, published by the American Institute of Mining and Metallurgical Engineers, Inc., Technical Publication No. 476. Jos. F.

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*Wailes Dove-Hermiston Corp., New York, N. Y.

Putnam of the Standard Oil Company of California, points out in a paper delivered before the American Petroleum Institute at Chicago, November 13, 1930, many factors in electrolytic corrosion. Among them—that often a new line laid alongside of an old pipe line will act as an efficient galvanic cell in which the new pipe was anodic, with the result that rapid corrosion frequently took place on the new line.

One of the most recent developments in the protection of pipe lines against corrosion is what is known as Cathodic Protection, where current is actually put on the pipe line. However, in order to make such protection practical, from the power-cost standpoint, it is necessary that the line be coated with a high grade coating of higher insulating value. R. T. Falkenberg of the Industrial Division, Houston Office of the Westinghouse Electric & Manufacturing Company, in a report entitled, "Electrical Mitigation of Pipe Line Electrolysis," points out the power cost for this type of protection per mile per year, where the customer actually pays 2½ cents per k.w.-hour as follows:

Size of Line In.	Type of Coating.	Power Cost for Protection per Mile per Year.
6	Coal Tar Enamel	$3.00
18	Coal Tar Enamel	15.60
9	Hot Asphalt	88.00
18	Grease only	490.00

The above shows that this type of protection is relatively cheap provided a good type of coating is originally applied on the line. It is realized, of course, that the actual application of electric current to pipe lines for prevention of corrosion is not a matter of immediate interest to water-works men, except in so far as it indicates trends in other utilities.

H. S. Warren. I was much interested in Mr. Cowles' paper. In my paper I referred anonymously to the Hackensack Water Company situation. A year ago or more that case was first brought to my attention, and the story as it then appeared was very interesting because it seemed to signify something entirely new—that somehow even small alternating currents on the water pipes caused impairment of the water. I could not understand how such a thing could possibly occur, and so when we were given an opportunity to get in touch with these experiments we accepted very gladly, not because of any direct interest in the outcome one way or the other, as a company, but because as a matter of scientific research it was intriguing. One of my associates has been following this work quite closely. I myself went over to the place where the experimental pipes that Mr. Cowles has referred to are set up, and tested some of the various samples of water, but I must say they all tasted alike to me. I could not tell one from another. That rather bears out the sensations that I understand others who have been looking into this matter have derived. They have not been convinced of any impairment of the water, so far as I know. Also I looked over one of the reports that was made, I read it rather carefully, but it was not convincing to me, and I was not aware before that the water company had come to such definite conclusions that the water had been affected by the current.

If the current does affect the water, it must come about in some physical way, and I am much interested to learn how it could be. I am satisfied, as I stated in my paper, that very little of the current on a pipe can get into the water; almost none of it, in the case of alternating current, can actually flow through the water inside the pipe.

All I can say in conclusion is that I welcome the opportunity to continue coöperation with Mr. Cowles and his people. I understand the investigation is still in progress, and I do not think it has gone far enough as yet to justify any conclusions as to what the tests signify. Certainly there are no definite conclusions that can be agreed to by all concerned.

PROCEEDINGS.

CONNECTICUT SPRING MEETING, 1934.

PICKWICK ARMS HOTEL, GREENWICH, CONN.

Tuesday, May 1, 1934.

President E. Sherman Chase in the Chair.

During the morning the Association inspected the Filtration Works of the Greenwich Water Co.

President Chase introduced Mr. Oscar Tuthill, First Selectman, Town of Greenwich, who welcomed the Association to Greenwich. Dr. S. H. Osborn, Health Commissioner of Connecticut, next welcomed the Association to Connecticut.

PRESIDENT CHASE. For some years it has been the policy of the Association to meet once a year in Connecticut, or possibly in Rhode Island; at least to have a meeting which will be easily accessible to our Connecticut members, of whom we now have many, and we anticipate that our membership will increase.

Times have changed since the formation of the New England Water Works Association, and they have changed since the establishment of our by-laws, which call for monthly meetings in Boston with an annual convention in Boston, or possibly elsewhere. We have probably lost sight of the fact that with improved methods of transportation, improved highways, portions of New England which once seemed relatively inaccessible to the center of gravity of our membership are now no longer inaccessible and that it is relatively easy for the members in Boston, Springfield, Concord, N. H., and even Portland, Me., to jump into their cars and be down here in a relatively few hours. This is particularly impressed upon my mind due to the fact that almost twenty years ago today I first came to Greenwich. I was then inspecting the water supply of the Greenwich Water Company, which supplies water not only to the town of Greenwich but to the city of Port Chester over the state line in New York State, this inspection being on behalf of the State Health Department of New York. To make this inspection I had to take the New York Central train to Bedford Hills, hire a two-horse livery rig and drive from Bedford Hills, a matter of 40 miles, I think, across country to Greenwich, and that journey took all day long. Coming down from Boston yesterday, 200 miles from my home, I came down by automobile in just five hours. That contrast of the transportation methods and time required twenty years ago and the transportation methods and time required today illustrates what I mean when I say that there is no reason why the New England Water Works Association cannot for its, meetings perambulate around the New England states. It appears to be a simple matter for us to hold this spring meeting in the extreme southwestern portion of the New England states and bring together between 130 and 150 of our members.

I wish to express our gratitude to the local committee in charge of the arrangements for this meeting, Mr. Putnam of the Greenwich Water Company, Mr. Lavery of Bridgeport, and Mr. Scott of Hartford. We are indebted to the Greenwich Water Company for various courtesies, including transportation to the filter plant this morning.

Donald W. Foster. Mr. President, I would like to move that the Association extend a vote of appreciation to Mr. Putnam and his committee for the hospitality they have shown us and the pleasant trip they gave us this morning.

[The motion is duly seconded and carried.]

A paper, "Electrical Grounds on Water Pipes," was read by H. S. Warren, Protection Development Engineer, American Telephone and Telegraph Co., New York, N. Y.

A paper "The Corrosion Problem," was read by Harold C. Chandler, Chemist in charge of Purification, Greenwich Water Company, Greenwich, Conn.

A discussion of Mr. Warren's paper, prepared by Charles F. Meyerherm, President and Engineer, Albert F. Ganz, Inc., New York, N. Y., was read by Mr. Edward E. Miner, Engineer and General Manager, New Haven Water Company. Mr. M. W. Cowles, Health Officer, Hackensack Water Company, New Milford, New Jersey, read a written discussion of Mr. Warren's paper. The general discussion was participated in by Messrs. Warren J. Scott, Roger W. Esty, R. M. Palmer, George F. Merrill, Henry T. Gidley, William Jay Willson, Elwood L. Bean, Gordon M. Fair, and D. B. Stokes of U. S. Pipe & Foundry Company. Mr. Warren closed the discussion.

(*Adjourned.*)

New Hampshire Spring Meeting, 1934.

Manchester Country Club, Manchester, N. H.

Wednesday, May 23, 1934.

President E. Sherman Chase in the chair.

President Chase introduced Mr. Albert F. Clough, Senior Alderman of the City of Manchester who welcomed the Association in the name of Mayor Caron.

Secretary Gifford announced the election to membership of the following:

Members: Charles W. Easter, Superintendent, Claremont, N. H.; George A. Reed, Water Commissioner, Montpelier, Vt.; Harry G. Northrop, Superintendent, New Milford, Conn.; Robert F. Campbell, Superintendent, Milford, N. H.; Frederick E. Green, Manager Water Works, Littleton, N. H.; Augustus J. Masefield, City Engineer, Brockton, Mass.; Harold P. Reynolds, Superintendent, Somersworth, N. H.

Corporate Member: Laconia Water Company, Laconia, N. H.

A paper "Development of Manchester Water Works," was read by J. H. Read, Assistant Superintendent, Manchester Water Works, Manchester, N. H.

A paper "New High Service Reservoir, Manchester, N. H.," was read by Percy A. Shaw, Superintendent and Engineer, Manchester Water Works, Manchester, N. H.

The President. It is forty-seven years ago that the New England Water Works Association met in Manchester. We have with us today two of our members who were members then: Mr. Thomas and Mr. John C. Chase. Mr. Thomas was in attendance at that convention, but Mr. Chase was in the South at that time and could not be here except in spirit.

Remarks by Messrs. Chase, Sullivan and Thomas.

John C. Chase.* This has been a red letter day for me. It is the fiftieth anniversary, within a few days, of my election to membership in the New England Water Works Association, of which I am now the senior member. There are several other organizations of which I have been a member a much longer time, but for none of them have I a greater affection than for this one, which I think is evidenced by my attendance at its meetings. Born in the nearby town of Chester, some ten miles away, I was familiar from my earliest recollection with Manchester and its environs.

I came here in 1869, upon my graduation from the academy at Derry, and entered the office of Mr. Joseph B. Sawyer, civil engineer, and with George H. Allen, who afterwards became the city engineer, assisted Mr. Sawyer in making the surveys for the water company which Mr. Shaw has mentioned. That was practically the same scheme that was afterwards adopted, only, instead of having the reservoir on the hill, it was in the valley, a few hundred feet nearer the city and some 25 feet lower than the site of the present reservoir. This project was rejected by the city, as Mr. Shaw has mentioned, and nothing was done for two years, when the great fire of 1871,— at least to Manchester it was a great fire,— crystallized into action the necessity for having a first class public water supply.

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* Derry, N. H.

Mr. William J. McAlpine, an engineer of note had been consulted, and later Colonel Fanning was secured to design and construct a system of water works. I had returned to the city to spend my summer vacation in the office of Mr. Sawyer, and we started in on the preliminary surveys, and I continued as an engineer on construction until the completion of the work in 1875 and am the only survivor of the force. The first construction was the laying, late in the fall of 1871, of about a mile of pipe with several hydrants, which was connected to the supply main of the Amoskeag Manufacturing Company, which insured much needed fire protection, and the supply of water was continued by the Amoskeag Company until the completion of the city's system some three years later.

This has been dealt with so thoroughly by Mr. Shaw that there is little that I can add, except some minor details which are not of any particular value. I am of the opinion, however, in the light of later developments that the gravity supply from Maple Falls would have been the most desirable source of water supply for the city. Of course I may be in error in some details as to the exact area that could be relied upon, but there is no question in my mind that if Maple Falls had been further investigated, a sufficient quantity could have been added later, if necessary, to make the general supply of the city of Manchester come from a section that would insure freedom from contamination, and preserving Lake Massabesic for unrestricted park purposes, unexcelled by any city with which I am a acquainted.

It has been a great pleasure to be here today and to see the remains of what we labored so zealously to build in the years 1872, 1873, and 1874. Practically all that is visible are the reservoir and the pumping station. The interior of the pumping station is entirely changed, the cement-lined pipe has been replaced with cast iron, and the additional high-service supply and the reservoirs and the pumps are entirely new. It is a generally rebuilt system, but I think the foundation was well laid, and I can pay merited tribute to its management, for nearly three score years, an original investment of about six hundred and fifty thousand dollars increasing to over four million.

While I might continue with these reminiscences I forbear with an expression of my great pleasure at being present and realizing that after so many years I have this opportunity of seeing the old place under such pleasant auspices.

William F. Sullivan.* It must have been a farsighted group of men in Nashua who, a number of years before Manchester, Lowell, and Providence, started water works, when Nashua had a very small population, and then carried on through these almost eighty years. We have always found that Nashua, in our own county, was a place to look up to for large projects.

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* President, Pennichuck Water Works, Nashua, N. H.

I am interested in the parallel between Manchester and Nashua in Mr. Read's paper, where he says that Manchester in its early days practically pumped all of its water, using lake water for the purpose, and raising the water 113 ft., requiring 7½ gal. to put one gallon in the reservoir.

Everybody has heard of that eminent water works engineer of the days of Mr. Chase: John T. Fanning. I was quite impressed many years ago by the opportunity to go to Manchester and meet a gentleman by the name of John T. Fanning, a civil engineer, because I had heard and read about John T. Fanning, and the work that he had accomplished in regard to water supplies was classic in its way.

Nashua had adopted a water supply whereby it, too, pumped water with water, and in the early days pumped practically 100 per cent.; even today we pump approximately 90 per cent. of all water with water. Manchester evidently emulated Nashua at that time.

As to cement-lined pipe, we too had some of it, and we discarded it after a few years. That was before my time. We are in the same county and look up to Manchester for many things. We find that Manchester is a progressive city.

Mr. Shaw mentioned planning for the future in mill towns. We do hope that the mill towns will still continue to grow, and we hope now, with the N.R.A., whereby we have leveled up the hours of labor and the minimum wage, that places like Manchester and Nashua will be able to survive.

I was much impressed with Mr. Shaw's remarks in regard to the C.W.A. I think a great mistake was made in Washington in regard to the handling of the P.W.A. There was too much red tape. A better result was obtained by the C.W.A. when the President advised to "go to it, spend the money, and increase the purchasing power of the United States." I believe that purchasing power could have been set free if they had gone into Manchester or some other city and said, "Look to the financial responsibility in granting applications without too much red tape."

I am glad to see my friend, Mr. Chase, here. He is still a neighbor of ours, ten miles away in Derry.

I see here also Mr. Thomas, who I know has been a member of the New England Water Works Association almost as long as Mr. Chase. He was a crony of Charlie Walker. Anybody who ever knew Charlie Walker knows that he was an astute, strong man,— a strong-willed superintendent of Manchester, who took the law unto himself when he burned all the cottages and all the camps on Massabesic, knowing that he might be sent to jail for life. I know he would enjoy being here today.

I know that Mr. Thomas remembers Charlie Walker. Mr. Thomas, I believe, was here forty-seven years ago at the meeting of the New England Water Works Association in Manchester. [*Applause.*]

R. J. THOMAS.* I attended the New England Water Works convention at Manchester, which was the first water works convention that I attended as a member. I came from the city of Lowell. I remember it with a great deal of pleasure. Anybody's first meeting is more apt to be remembered than any other meeting afterwards.

I remember, of course, that it was a great pleasure for me to meet Mr. Walker at that time. I knew him for many years afterwards. He was a man with a great sense of humor, and not only did his words convey it but his expression. He was the typical Yankee that I knew as a boy. Whether the words in themselves expressed his meaning was not the point. It was the way he expressed the thing.

I remember one time coming to Manchester and having a talk with him. He was telling how long he had been there as superintendent. I said to him, "Well, how are they ever going to get rid of you, Charlie?" "Well," he said, "I don't know, unless they wait until I shuffle off."

As to not having had another convention in Manchester, the explanation is probably that at that time the delegates had to sleep with three beds in a room. That was the accommodation they had in Manchester then. We had a convention in Lowell three years before that, in 1884, but they have never had another one there since. The same reason applies to Lowell that applies to Manchester, and it still applies to Lowell.

THE PRESIDENT. The arrangements and the entertainment we have received call for a rising vote of thanks to the Water Commissioners of Manchester, and to the local committee headed by Mr. Shaw, assisted by Mr. Calderwood, Mr. Bean, and Mr. Read.

[*A unanimous rising vote is taken.*]

As your president I wrote a short time ago to the President of the Institution of Water Engineers in London, suggesting some free and mutual coöperation with respect to the exchange of papers of outstanding merit, and also coöperation in the case of members of the two societies visiting one or the other country. In reply to my communication I have received the following letter from Mr. Fox, President of the Institution of Water Engineers of England:

> I am very glad to get your letter of the 14th inst., with which I am in very cordial agreement.
>
> I think your ideas for coöperation are eminently practicable, and I am sure there should be no difficulties.
>
> As regards your second suggestion, I take it that by exchange of papers, you mean exchange as between the respective Institution's offices, as for every member of the opposite Institution to have a copy would, I think, mean rather a big bill.
>
> Personally, if I was in the fortunate position of being able to cross the Atlantic again, I should not hesitate to ask for any assistance, both from you whom I have met, or from any American water engineer whose works I wanted to see. Further, I know that any of us would be only too glad to be of any assistance we could to any of your members especially, or to any others.

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*Lowell, Mass.

I also wrote to several of our fellow members in foreign countries. You may not be aware of the fact, but we have a dozen or fifteen members of this Association who do not reside either in the United States or in Canada. The other day I received a latter from our member in Stockholm, Sweden. He writes as follows:

> I beg to thank you most cordially for your letter of April 24, 1934, with your kind invitation to call on you and the officers of the Association, should I come sometime on a visit to the United States, and to submit a paper for publication in the JOURNAL.
>
> I appreciate very much, indeed, this letter of yours, as it shows that the Association cares also for its foreign members. I value my membership of the New England Water Works Association especially, as it was my first contact with American colleagues when I visited the States nearly 20 years ago, i.e., in 1915–16. I have been glad to pay my annual membership fee ever since — although the Swedish-American currency for some time was not exactly favorable — and to receive the Association's valuable JOURNAL.
>
> If and when I come again to the U. S. A. is rather uncertain. Should I come sometime, however, I will not fail to accept your kind invitation.
>
> Preparing a paper for the JOURNAL is a tempting suggestion of yours, which I am sorry not to be able to comply with at once, as I am extremely busy and will be so for some time to come, but I will keep it in mind and will be glad to do something on that line when I get an opportunity.
>
> With kindest greetings to yourself, dear Sir, and to my colleagues of the Association, I am,
>
> Sincerely yours,
>
> (Sgd.) WALO VON GREYERZ.
> Major, Swedish Royal Corps of Engrs., Consulting

A general discussion on the subject of "Sanitation of Watersheds" was opened by Arthur D. Weston and participated in by Percy R. Sanders, Percy A. Shaw, Leonard C. Robinson, Harold L. Brigham, Arthur C. King, Francis H. Kingsbury, Charles W. Sherman, and Leonard W. Trager.

NEW HEADQUARTERS OF THE ASSOCIATION.

The headquarters of the New England Water Works Association are now in Room 613, Statler Building, Park Square, Boston, Mass.

The new rooms provide convenient and comfortable quarters where members may meet informally. Available for reference in the reading room is a comprehensive selection of American and foreign technical publications and a complete file of the Journal of the Association.

The rooms are open on week days from 9:00 A.M. to 1:00 P.M. and from 2:00 to 5:00 P.M., except on Saturday, when the closing hour is 12:30 P.M. Miss Ullian, the assistant secretary, in charge of the office, will be glad to assist visitors in any way possible.

It is hoped that members will make frequent use of the new rooms.

REPORT OF COMMITTEE ON HYDRANT MARKINGS.*

To the New England Water Works Assocciation:

Your committee on the Standard Markings of Fire Hydrants submits the following report:

This subject is of importance to all water utilities and fire departments. If every hydrant in a water works is tested to learn the amount of water it will deliver at a given residual pressure and the hydrant is marked to show the result, the fire department will be able to work to better advantage and the water-works officers will have valuable records. If the system of marking is uniform, fire departments from other towns will be able in time of emergency to locate at the proper hydrants. It is desirable that the capacity of all hydrants be determined at the same residual pressure and that the full capacity when supplying pumpers be known. For this reason a residual pressure of 10 lb. per sq. in. has been adopted for the standard.

Markings. Markings should be determined by flow test, and should be divided into three classes, A, B, and C.

Class A. Hydrants which have sufficient capacity to supply 1 000 or more gallons per minute.

Class B. Hydrants which have sufficient capacity to supply not less than 500 gallons per minute.

Class C. Hydrants with insufficient capacity to supply 500 gallons per minute.

Post Hydrant Markings. Barrels of all hydrants should be painted chrome yellow for visibility.

Class A. Tops and nozzle caps should be painted green.

When the capacity of the hydrant is greater than 2 000 gallons per minute, a number should be painted on the barrel of the hydrant signifying the number of thousand gallons per minute exceeded.

Class B. Tops and nozzle caps should be painted yellow.

Class C. Tops and nozzle caps should be painted red.

The colorings conform to standard traffic signals with green the most desirable, and red the least desirable.

Flush Hydrant Colorings. All location markers for flush hydrants should carry upon their background, the colors designating the class in which that particular hydrant falls.

All flush hydrant covers should carry upon the under side, preferably within the circle, the proper color as a background upon which any necessary data should be stencilled in black.

Respectfully submitted,

(Signed) HARRY U. FULLER,
GEORGE H. FINNERAN,
FRANK E. WATERMAN.

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*EDITOR'S NOTE. The report of this committee is reprinted in full instead of calling attention to certain errata in the report as printed in the June issue of this JOURNAL.

GEORGE WARREN FULLER.

George Warren Fuller, a member of this association since 1893, died at New York, N. Y., on June 15, 1934, after a brief illness.

For many years Mr. Fuller had been engaged in consulting practice in the field of sanitary engineering, in recent years as the senior member of the firm of Fuller & McClintock, of New York.

Mr. Fuller was born at Franklin, Mass., December 21, 1868. After graduating with the degree of Bachelor of Science from the Massachusetts Institute of Technology in 1890, he studied for about a year at the University of Berlin and in the private office and laboratory of Piefke, engineer of the Berlin (Stralau) water works.

Returning to America, Mr. Fuller devoted about nine years to research on methods of purifying water and sewage, from the engineering, chemical and biological viewpoints. From 1891 to 1895, he was a bacteriologist at the Lawrence Experiment Station of the Massachusetts State Board of Health, during the latter part of that period being in charge of the station, succeeding the late Allen Hazen. The experiments on water purification at the Lawrence station, which was established only four years before Mr. Fuller went there, laid the groundwork for much of modern sanitary engineering practice.

In 1895 Mr. Fuller went to Louisville, Kentucky, where for two years he conducted experiments on the suitability of the various available processes of water purification with rapid filters for purifying the turbid Ohio River water at Louisville, a water having wide variations in composition. His work demonstrated the ability of suitable coagulation and rapid sand filtration to cope with water of such a character, thus laying the foundation for rapid filtration as practiced in this country for the past 30 years.

Following the Louisville studies, Mr. Fuller had charge of similar researches at Cincinnati, Ohio, for a period of 14 months. As a result of these researches he concluded that proper coagulation of the water prior to filtration was imperative, in order to purify the water satisfactorily, and established many other fundamentals of water purification. His studies, moreover, demonstrated the superior efficiency and economy of the mechanical system of filtration, as compared with the slow-sand system, especially for turbid and highly colored waters.

In 1899 Mr. Fuller entered private practice as an engineer, with an office in New York. In 1901 he formed a partnership with the late Rudolph Hering under the firm name of Hering & Fuller; later the partnership was enlarged to include John H. Gregory and the firm name was changed to Hering, Fuller and Gregory. After dissolution of this firm in 1911, he continued practice under his own name until 1916, when he formed a partnership with the late James R. McClintock. He continued practice under the firm name of Fuller & McClintock until his death.

During the World War, Mr. Fuller was a member of a Central Committee at Washington having to do with the engineering, planning, and sanitation of the various army camps. He was consulting engineer to the United States Public Health Service and to the Construction Division of the U. S. Army.

In 1924 and 1925 Mr. Fuller was chairman of the Engineering Board of Review of the Sanitary District of Chicago on the Lake Lowering Controversy and Program of Remedial Measures. In this capacity he labored with 27 other consulting engineers upon the many problems arising out of the intimate relation between the disposal of the sewage of the Sanitary District and the use of water from Lake Michigan. He was retained this year by the government to advise a special Board of Review on the processes to be used in proposed additions to Chicago's sewage disposal works.

For many years Mr. Fuller was intimately connected with the improvement of sanitary conditions in New York City. He served as a consultant on sewerage and sewage disposal for the Metropolitan Sewerage Commission of New York and in 1929 he reported to the city upon the Wards Island sewage treatment plant. His firm afterward prepared the plans for this project which is now partially constructed. From 1906 until his death he was consultant to the New York Board of Water Supply on various sanitary problems connected with the development of the Catskill reservoirs and supply system.

During his professional career, Mr. Fuller served as consulting engineer for major water works and sewerage improvements in more than 150 large cities in this country and abroad, one of his most recent studies being the one for a Metropolitan Sewerage System for Providence and nearby municipalities. Mention must also be made of Mr. Fuller's services as an expert witness in important cases, where his wide experience made him valuable.

Mr. Fuller always took a keen interest in activities aimed toward the standardization of practices related to public health. He contributed largely to the development and widespread adoption of the Standard Methods of Analysis for Water and Sewage, sponsored by the American Public Health Association. As chairman of the Council on Standardization of the American Water Works Association, he, more than any other individual, was responsible for the successful publication of the Manual of Water Works Practice.

Mr. Fuller had been President of the American Public Health Association and of the American Water Works Association, and Vice-President of the American Society of Civil Engineers. Among other professional and scientific societies of which he was a member were the American Chemical Society, American Institute of Consulting Engineers, American Society of Bacteriologists, American Society of Mechanical Engineers, the Franklin Institute, the Engineering Institute of Canada, the Institution of Civil

Engineers of Great Britain, L'Association Générale des Hygiénistes et Techniciens Municipaux of France, and the Verein Deutscher Ingenieure.

Mr. Fuller was elected to The Engineering Foundation in 1931, served as Vice-Chairman in 1932, was elected Chairman in 1933 and held that office at the time of his death.

He was the author of many professional papers and of the following books: "Water Purification at Louisville," 1898; "Sewage Disposal," 1912; and, with the late J. R. McClintock, "Solving Sewage Problems," 1926.

Mr. Fuller's activities were not alone in the sanitary field. He was an expert in the valuation of public utilities, having been connected with appraisal of many water works properties as well as the Pittsburgh Street Railways, the Philadelphia Rapid Transit, and the International Railways Co. of Buffalo.

By his death the New England Water Works Association has lost one of its most distinguished members, and the country one of its foremost sanitary engineers.

HARRY W. CLARK
HARRISON P. EDDY
ROBERT SPURR WESTON.

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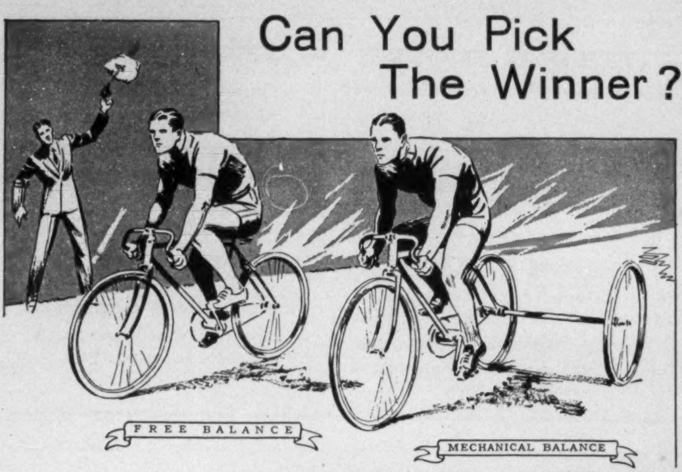

Two wheels or three? If you were betting on this race you wouldn't hesitate a minute. That third wheel is just a crutch for the rider who cannot balance himself on two wheels.

Free balance is an advantage in meter performance, too.

You see why when you watch the nutation of the Hersey V-Type Disc Piston. The Piston is so perfectly balanced that the flow of water alone keeps the spindle traveling in a perfect circle. No mechanical compensation is needed.

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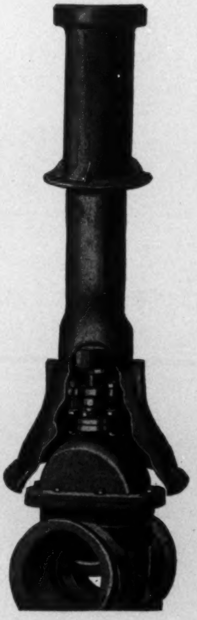

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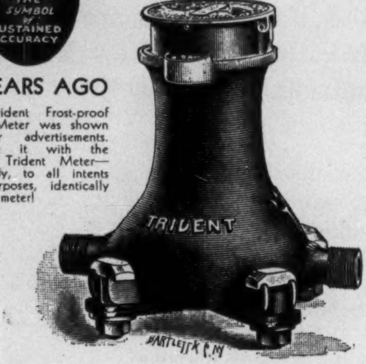

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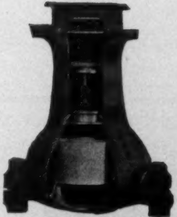

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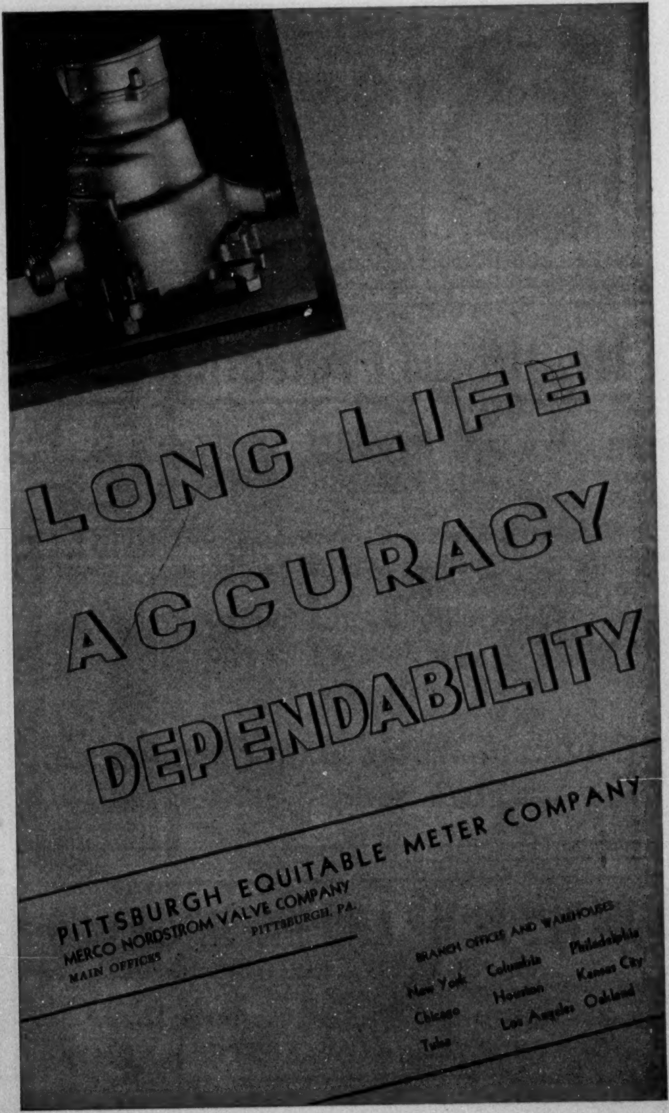

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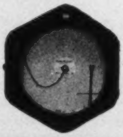

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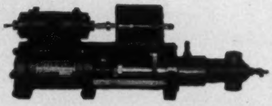

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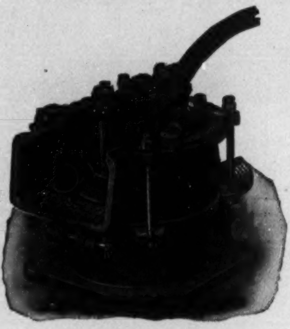

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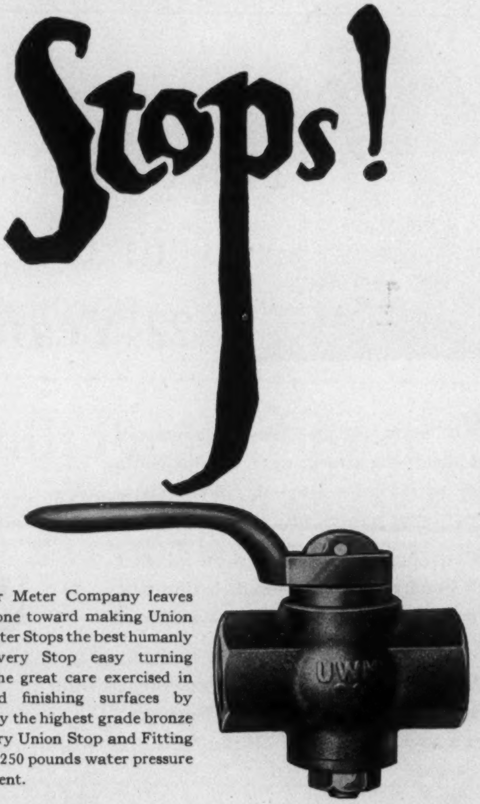

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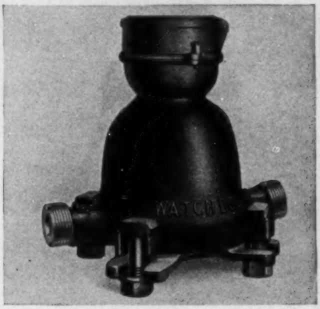

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The PERFECT METER is one that
MEASURES ALL of the WATER
ALL of the TIME
and NEVER wears out. . . .
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The NATIONAL METER COMPANY will
CONTINUE to LEAD the way
in the PRODUCTION of BETTER
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The splendid increase in our sales for the past seven months and the assured business for the balance of the year are evidence of the faith of the water works fraternity in our product.

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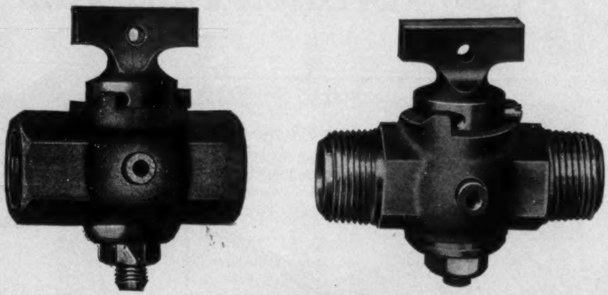

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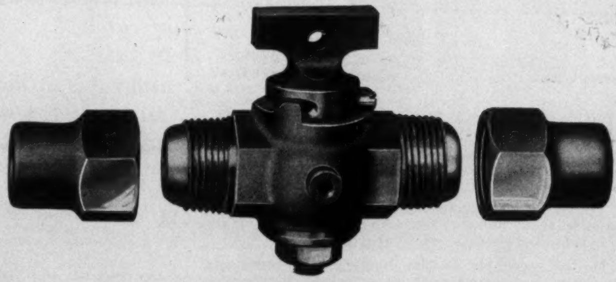
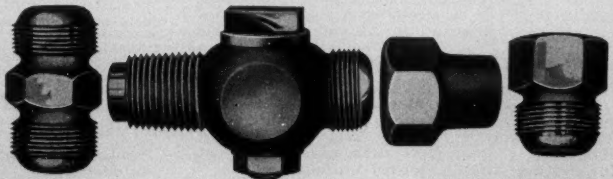


TEE HEAD NEWPORT STOP AND WASTE COCK
With Double Copper Tubing Connections



Cocks for ¾″ Copper Tubing have 1″ I. P. Male Threads and Cocks for 1″ Copper Tubing have 1¼″ I. P. Male Threads. This allows our cocks to be used with regular I.P. fittings when necessary.

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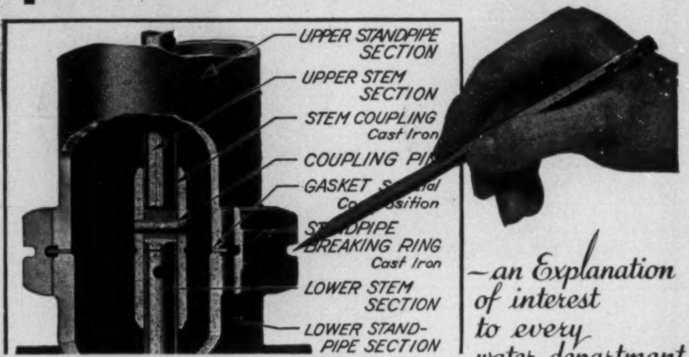
How the Safety Breakable Section functions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UPPER STEM SECTION
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GASKET Special Composition
STANDPIPE BREAKING RING Cast Iron
LOWER STEM SECTION
LOWER STANDPIPE SECTION

—an Explanation of interest to every water department superintendent and engineer

THE Safety Breakable Section of the Kennedy SAFETOP Fire Hydrant does not break from a smashing collision because it is a thin or weak section, but because the stress is localized and concentrated at this point.

The Safety Breakable Section is proportioned to be at least as strong as the standpipe of other makes of hydrants of the same inlet valve size.

During assembly of the hydrant, the standpipe breaking ring is tightened as a turn-buckle against the upper and lower standpipe sections.

The thickness of the metal and the initial strain in this ring brought about by tightening it have been calculated so that the stresses generated by a smashing collision will strain the iron at the Breakable Section beyond its ultimate tensile strength before this condition develops in the adjacent sections of the standpipe.

The accuracy of our calculations and the correctness of this design have been proved beyond question by more than 100 breakages of SAFETOP Hydrants on factory tests, demonstration tests of installations, and accidental collisions.

WHEN the Kennedy SAFETOP Fire Hydrant is struck by a smashing impact which *no* hydrant could resist, the Safety Breakable Section is cleanly fractured, the upper standpipe and stem assembly is dislodged without damage, there is no flooding, and the occupants of the colliding vehicle are protected from serious personal injury.

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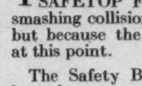
The Fire Hydrant with the Safety Breakable Section

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SAFETOP FIRE HYDRANT

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Type of Eddy Hydrant Popularly Used

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Hydrants and Valves

BUILT TO MEET EVERY EXACTING REQUIREMENT OF WATER-WORKS SERVICE

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The Drip Rod can be removed without interfering with the hydrant in any manner —
The position of the stem of the hydrant indicates accurately the position of the valve —
Whatever can pass the valve opening will pass the standpipe —
No frost case necessary —
All of these points are explained thoroughly in our catalogue, which will pay you to study.

The Eddy Valve, Too

Has its distinctive and individual features. The double disk gates are free to adjust themselves in different positions every time the valve is closed, thereby keeping smooth and tight faces. And two bronze hooks on the ball loosely engage with the gates to prevent them from spreading at the top. The center bearing gates are forced to their seats with equal pressure at all points. There is a good deal more worth knowing about Eddy Valves. Further details will be sent for the asking.

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The Eddy line of water-works products also includes horizontal and vertical check valves, foot valves, hydraulically operated valves, indicator posts, etc.
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National-Boston Lead Co.

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Agents for

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It makes an absolutely tight joint which will withstand the highest pressure, yet be sufficiently elastic to allow considerable sagging or settling of the pipe without danger of a leak.

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PIG LEAD

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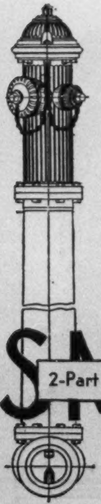
The upper section will always break first. It can easily be renewed. And of course there can be no leakage of water because the main valve is of the compression type.



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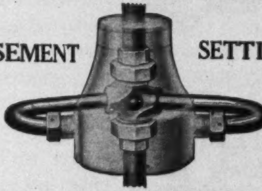
METER COUPLING
for BASEMENT SETTINGS



- ● 1 **Meter set horizontally** at desired height in vertical pipe without ells, nipples or couplings.
- ● 2 **All copper water way.** No rusting or corrosion. Freezing will not burst it.
- ● 3 **Smooth oversize tubing** and sweeping bends, maximum flow.
- ● 4 **Meter changes** do not disturb piping whether the meter is in or out.
- ● 5 **On new services** it serves as a spacer to connect in the piping.
- ● 6 **Provides a permanent** electrical ground connection.

May We Give You Further Information About the Copperhorn?

The FORD METER BOX COMPANY
Wabash, Indiana

Tap the Main and Follow Thru
with the
Hays Copper Service Method

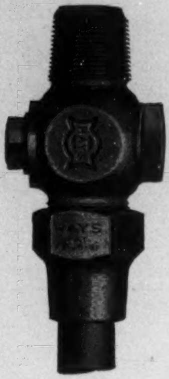


Fig. 108E

The Hays method of joining copper pipe has made it the choice of hundreds of far-sighted water works officials. The Hays Copper Service Method covers every underground service requirement, it makes copper "talk" in any good pair of hands.

Once a Hays Connection is laid and buried it stays down, not for 5, 10 or 15 years, but for generations. $99\frac{9}{10}\%$ pure copper in heavy wall tubing and the patented Hays connection can take any punishment that settling soil, vibration, twist, or pull can give. It's a permanent method that puts service replacement costs on the toboggan.

Write for the complete story on the Hays Copper Service Method.

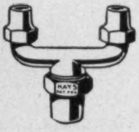


Fig. 125G

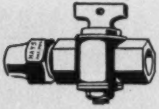


Fig. 82C

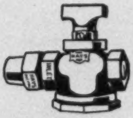


Fig. 79C

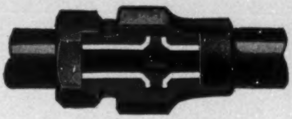


Fig. 120S

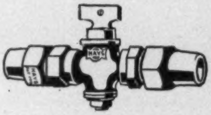


Fig. 54E

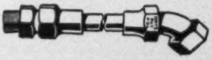
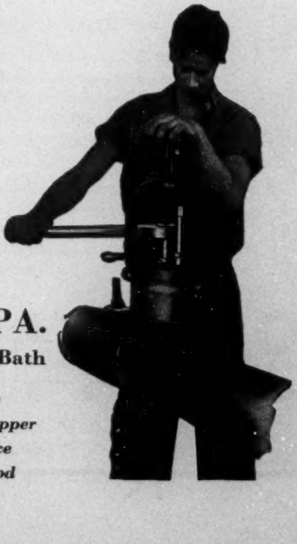


Fig. 119E



HAYS MFG. CO., ERIE, PA.

Plumbing Brass Goods from Street to Bath

The
Hays Copper
Plumbing
Method

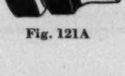
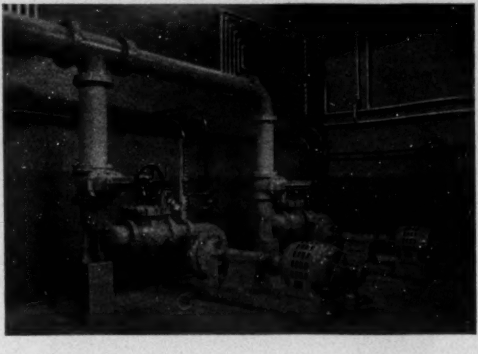


Fig. 121A

The
Hays Copper
Service
Method



▲ ▲ ▲

City of Wakefield Pumping plant designed by Weston and Sampson, Consulting Engineers, is equipped with two 5-in. sewage pumps with direct connected 20 h.p. 3-phase, 60-cycle, 220-volt, 1200-r.p.m. Type "HV" ball bearing motors. The total rated capacity of the plant is 1400 g.p.m. against a 52-ft. head.

▼ ▼ ▼

Motors and Pumps Built and Installed Under *One* Guarantee

These pumps handle unscreened sewage and thus eliminate the expense and trouble of screening as they are capable of passing large solids without clogging.

Fairbanks-Morse sewage pumps are built in types and capacities to meet every requirement and many towns and cities throughout the country have found in them the practical solution of sewage pumping problems.

A Fairbanks-Morse engineer will be glad to discuss your requirements with you. His services are at your disposal without cost or obligation.

Fairbanks, Morse & Co.

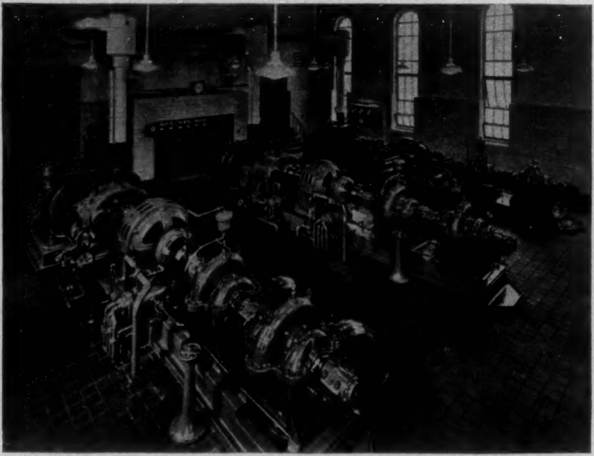
178 Atlantic Ave. Boston, Mass.

DE LAVAL

Geared Turbine Driven

PUMPS and GENERATORS

The Most Modern and Efficient Pumping Station in New England



CITY OF NEWTON, MASSACHUSETTS

R. H. ELLIS, Water Commissioner WESTON & SAMPSON, Consulting Engineers

The three units are designed for 4¼, 6 and 8 M. G. D. against 272, 295 and 340 feet pumping head respectively with steam at 230 pounds gage, 125 degrees superheat 29 inches vacuum.

Acceptance tests showed each unit exceeded its guarantees by a liberal margin.

TURBINE EQUIPMENT COMPANY
OF NEW ENGLAND
80 Federal Street Phone LIB erty 5993-4 Boston, Mass.

New England Representative for
DE LAVAL STEAM TURBINE COMPANY
TRENTON, N. J.

ARE YOU PAYING to be MYSTIFIED?

"The Only Safe Water
Is a Sterilized Water"

AS ENTERTAINMENT it's worth paying money to be mystified by a clever magician pulling white rabbits out of a silk hat. But—there's no entertainment in being mystified by the internal ailments of a housed-in chlorinator. That's why we suggest W & T Visible Vacuum Control chlorinators for your plant. All the working parts are under the glass bell jar in full view—with no chance for minor operating irregularities to develop into major repair problems.

For that reason, if for no other, you may count on low maintenance costs, satisfactory operation and long life from W & T Visible Vacuum Control equipment.

And this is equally true whether your problem be one of water sterilization, swimming pool disinfection, sewage treatment or any of the allied sanitary and industrial processes of chlorination.

A card will bring you the details.

WALLACE & TIERNAN CO., Inc.

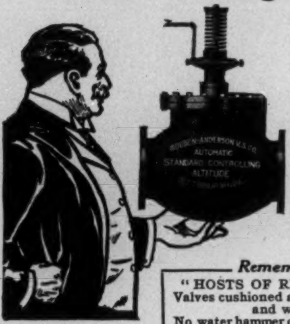
Manufacturers of Chlorine and Ammonia Control Apparatus

NEWARK, NEW JERSEY

Branches in Principal Cities
Main Factory: Belleville, N. J

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Altitude Valves



We have enlightened many a water user in municipalities, in industrial plants and on railroads, as to the adaptability of these Golden-Anderson Valves, and as to their function of SAVING, and of eliminating troubles.

For automatically maintaining Uniform Stage of Water in Tank, Reservoir or Standpipes. Doing away with the annoyance of Freezing and Float Fixtures inside or outside of Tanks.

"Three Ways of Closing These Valves":

1st —Automatically, by water.
2nd—By Electricity, if desired.
3rd —By Hand

May also be arranged to automatically close when a break occurs in the mains. When necessary they may be so connected as to "work both ways" on a single line of pipe. No valves or fixtures inside or outside.

**New Haven Water Co.
New Haven, Conn.
now using
2-24"
1-16"
2-12"
1-10"
ALTITUDE VALVES**

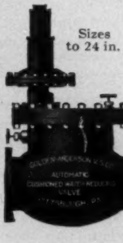
Remember!

**"HOSTS OF REFERENCES"
Valves cushioned at all times by air and water
No water hammer or bursting mains**

30 of these ALTITUDE VALVES sizes, 6" to 24" serving the City of Los Angeles, Calf., now.

GOLDEN-ANDERSON Pat. Automatic Cushioned Water Pressure Regulating Valves

1. Maintain a constant reduced pressure regardless of fluctuations on high pressure side.
2. Perfectly Cushioned by water and air. No metal-to-metal seats.
3. The best valve made for maintaining a constant low pressure where consumption is continuous.
4. Operates quickly or slowly as required — No attention necessary.
5. Positively no hammering or sticking.



Sizes to 24 in.

GOLDEN-ANDERSON

Patent Automatic Cushioned Controlling Float Valves

They carry a constant water level in feed water heaters, Tanks and Reservoir by perfectly controlling the flow of makeup water.

Operated by protected enclosed copper float.

Cushioned by both air and water.

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3. Floats Swivel to any Angle — Most Satisfactory Float Valves Known.
4. No Metal-to-Metal Seats — No Water Hammer or Shock.
5. Cushioned by Water and Air.

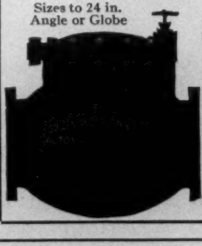
GOLDEN-ANDERSON
AUTOMATIC
FLOAT VALVE
CUSHIONED
PITTSBURGH

Angle or Globe

Sizes to 24 in.

GOLDEN-ANDERSON Patent Automatic Double Cushioned Check Valve

Sizes to 24 in.
Angle or Globe



Automatically prevents reverse flow of pressure.

Perfectly cushioned to prevent shock or hammer.

Especially adapted for water works to prevent disastrous reverse flow of pressure due to pumps stopping.

Arranged so that quick or slow operating may be obtained.

Golden-Anderson Valve Specialty Co., 1325 Fulton Bldg., Pittsburgh, Pa.

Main's Hotcoating for the inside of standpipes and water tanks, will stop all pitting and corroding, and is guaranteed for seven years.

Also

Main's Coverall Salt Air Paint, for the outside of standpipes and water tanks, guaranteed for four years.

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The "COREY" Hydrant

Why you should use GENUINE COREY HYDRANTS

Water to Nozzles quicker than other Hydrants.

Standpipe can be removed and replaced without shutting off water in main.

Ease of operation insured by knuckle joint principle.

Only 13 turns to completely open or completely close, but full flow with only 4 turns.

Nozzles screwed in — not leaded.

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Will not flood if broken.

Positive Drip — cannot freeze.

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New England Water Works Association

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Meter Rate Sheets:	Single sheet	0.05
	100 sheets, in orange	2.50
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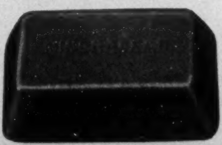

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MINERALEAD

For Jointing Bell and Spigot Water Mains

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OF PENNSYLVANIA
MERTZTOWN, PENNSYLVANIA

New England Sales Representative
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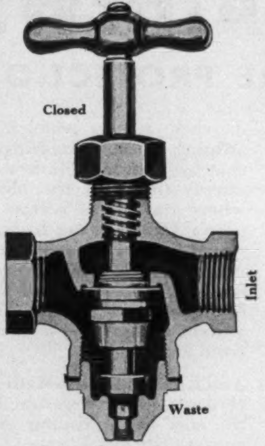
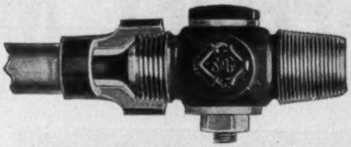


Gorham Compression Stop
and Waste Cock



Copper Flanged Corporation Stop

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Also Curb Cocks which eliminate Iron to Brass Corrosion both inside and out.

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When valves of the same general design as this one have been in use for 20, 30 or 40 years, without failure or repairs, it means something. It means that Ludlow valves can be trusted on any sort of water works or sewerage installation.

This long, successful record of service is due to *sound, simple design: rigid selection of materials and careful manufacturing methods.*

The record shows that Ludlows give permanent satisfaction.

The LUDLOW
VALVE MFG. COMPANY
TROY · · · · NEW YORK

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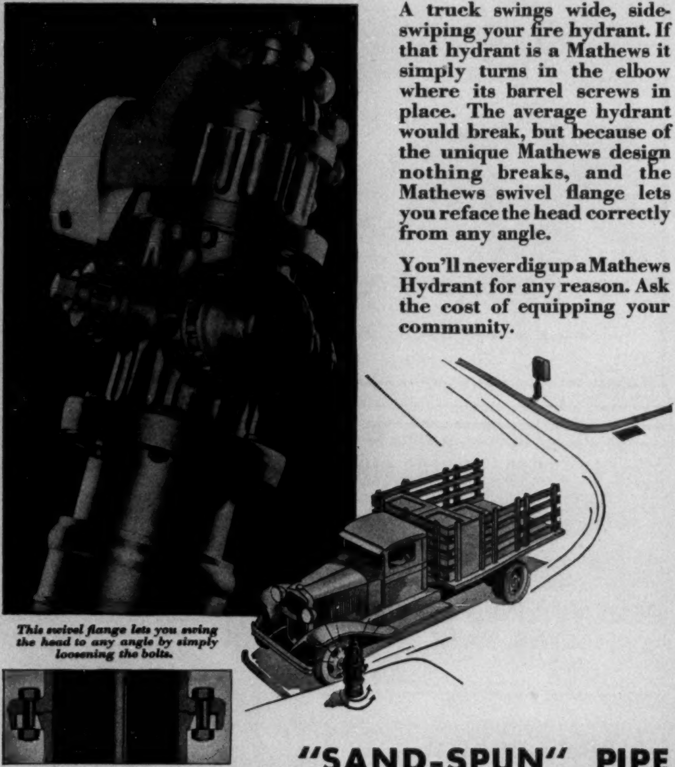
FOR PROTECTED FIRE PROTECTION

A truck swings wide, sideswiping your fire hydrant. If that hydrant is a Mathews it simply turns in the elbow where its barrel screws in place. The average hydrant would break, but because of the unique Mathews design nothing breaks, and the Mathews swivel flange lets you reface the head correctly from any angle.

You'll never dig up a Mathews Hydrant for any reason. Ask the cost of equipping your community.



This swivel flange lets you swing the head to any angle by simply loosening the bolts.

"SAND-SPUN" PIPE

"Sand-Spun" pipe is Cast Iron—a superior pipe with an individual sand mould for every pipe . . . Obtainable in 16½ ft. and 20 ft. lengths. These longer lengths save 30% to 60% in jointing materials and handling, as compared to 12 ft. lengths.

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ESTABLISHED IN 1803
400 CHESTNUT STREET
PHILADELPHIA

Advt. No. B-9 September, 1934

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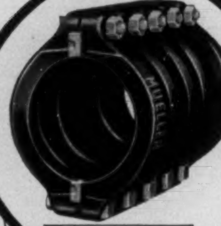
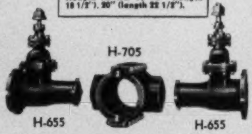
WROUGHT IRON PIPE. (See Pipe, Wrought Iron and Steel.)	



Mueller H-776 Heavy Pressure Split Repair Sleeves are furnished in the following range of sizes: 4" (length 12"), 6" (length 12 3/4" and 16"), 8" (length 13 1/4" or 18 1/2"), 10" (length 14 1/4" or 20 1/2"), 12" (length 16 1/2" or 22 1/2"), 14" (length 18 1/2"), 16" (length 18 1/2"). 20" (length 22 1/2").

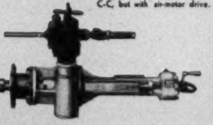


Heavy pressure tapping crosses for use with Mueller or other standard drilling machines are illustrated above with bell and spigot outlets and below with flanged outlets. Standard types are tested to 300 lbs. pressure.

H-660
H-710
H-660

The new Model "C-C" manually operated drilling machine is illustrated below. It makes cuts from 2" to 12" in any size of main. Outstanding features are greater compactness, greater drilling capacity, new ease of handling and a new positive, automatic feed

The Model C-1 similar to the C-C, but with air-motor drive.



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—and by—

THE MAN WHO USES THEM

THAT unvarying dependability of Mueller equipment is based on more than a half-century of research in the greatest of all laboratories—the laboratory of the *field!* Through seventy-five years of intimate contact with the practical problems of the man in the field, Mueller equipment can be said to have been designed as much by the man who uses it as by Mueller Co.

One of the most recent of these practical developments is the H-776 Heavy Pressure Split Repair Sleeve, illustrated opposite. Every water works should carry a proper range of these sleeves as insurance against service interruption.

Closely allied to the repair sleeves are the Heavy Pressure Tapping Crosses for making double branch connections in opposite directions under pressure. The Mueller Drilling Machines for use with these and similar Tapping Valves have been greatly improved during recent years as attested by the praise of water works men in every section of the country.

Consult your Mueller Catalog H for facts and details covering this and other Mueller Water Distribution Equipment. Play safe by using only this equipment that stands on an unequalled record of service delivered.

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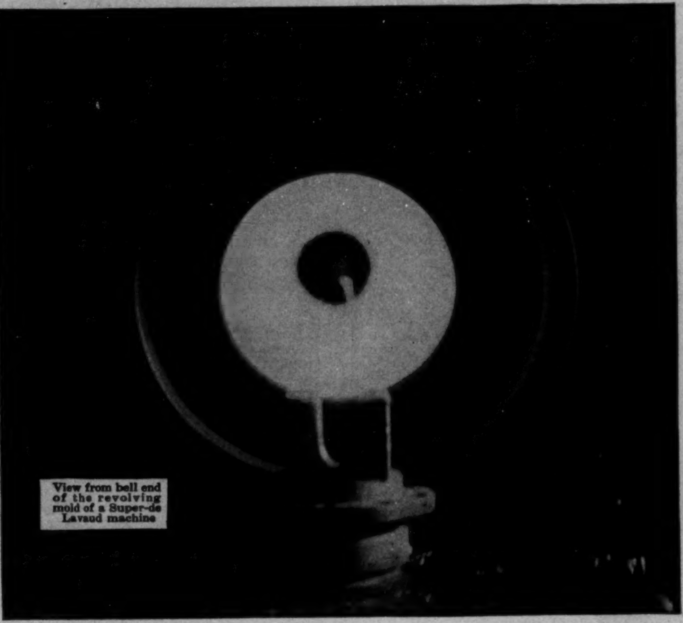
EQUIPMENT

CAST WITHOUT CHILL IN A METAL MOLD



View from bell end of the revolving mold of a Super-de Lavaud machine

When our technical staff undertook to find a way to cast gray iron against metal without chill there was no precedent to guide them. It had never been done commercially. After literally hundreds of experiments a commercially practicable method was discovered, perfected and patented. Today this method—the Super-de Lavaud process—is standard practice in our plants. Super-de Lavaud Pipe is *cast without chill in a metal mold.* It is stronger, tougher, more ductile. Impact resistance to handling and service shocks is doubled. The pipe does not shatter at failure in bursting tests. These outstanding advantages are obtained by the use of patented processes of centrifugal casting and annealing, described in a book we shall be glad to send on request.

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